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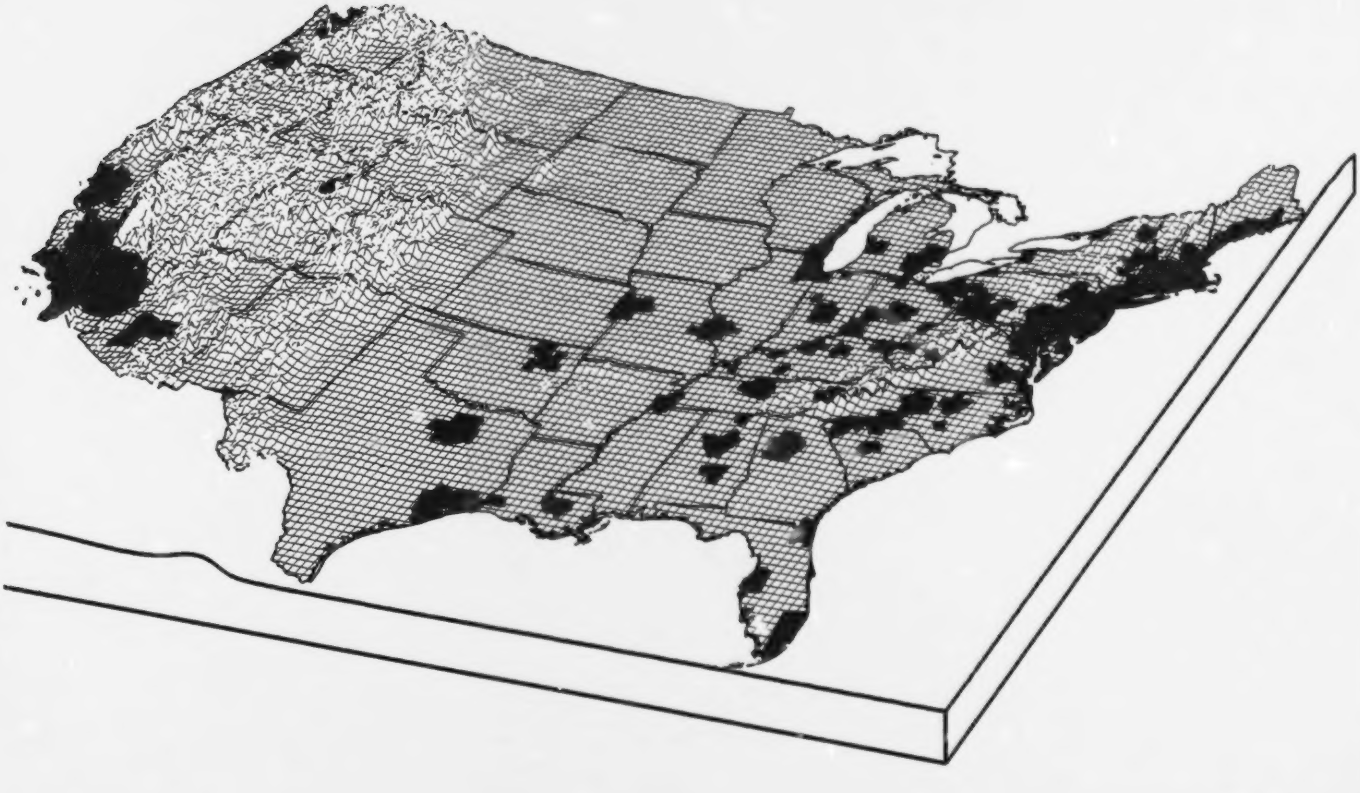

Areas Not Meeting the Ozone NAAQS, 1986-88

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16. ABSTRACT

This report presents national and regional trends in air quality from 1979 through 1988 for total suspended particulate, sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone and lead. Air pollution trends were also examined for the 5-year period (1984-88). Both national and regional trends in each of these pollutants are examined. National air quality trends are also presented for both the National Air Monitoring Sites (NAMS) and other site categories. In addition to ambient air quality, trends are also presented for annual nationwide emissions. These emissions are estimated using the best available engineering calculations; the ambient levels presented are averages of direct measurements.

This report also includes a section, Air Quality Levels in Metropolitan Statistical Areas (MSAs). Its purpose is to provide interested members of the air pollution control community, the private sector and the general public with greatly simplified air pollution information. Air quality statistics are presented for each of the pollutants for all MSAs with data in 1988.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Trends Emission Trends Carbon Monoxide Nitrogen Dioxide Ozone Sulfur Dioxide Total Suspended Particulates Lead Air Pollution Metropolitan Statistical Area (MSA) Air Quality Standards National Air Monitoring Stations (NAMS)		

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Technical Support Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711
March 1990

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This report has been reviewed by the Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, and has been approved for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use.

About the Cover: Areas Not Meeting the Ozone Standard During 1986-1988.

PREFACE

This is the sixteenth annual report of air pollution trends issued by the U. S. Environmental Protection Agency. The report is prepared by the Technical Support Division and is directed toward both the technical air pollution audience and the interested general public. The Division solicits comments on this report and welcomes suggestions on our trend techniques, interpretations, conclusions, and methods of presentation. Please forward any response to Dr. Thomas C. Curran, (MD-14) U. S. Environmental Protection Agency, Technical Support Division, Research Triangle Park, North Carolina 27711.

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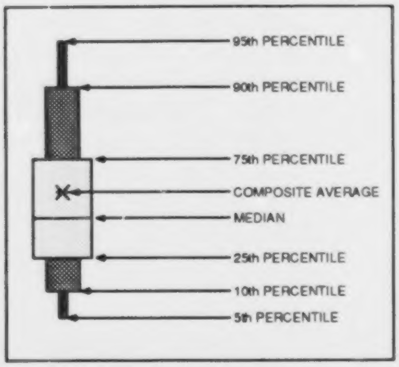
NATIONAL AIR QUALITY AND EMISSIONS TRENDS REPORT, 1988

1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

This is the sixteenth annual report[1-15] documenting air pollution trends in the United States for those pollutants that have National Ambient Air Quality Standards (NAAQS). These standards have been promulgated by the U. S. Environmental Protection Agency (EPA) to protect public health and welfare. There are two types of NAAQS, primary and secondary. Primary standards are designed to protect public health, while secondary standards protect public welfare, including effects of air pollution on vegetation, materials and visibility. This report focuses on comparisons with the primary standards in effect in 1988 to examine changes in air pollution levels over time, and to summarize current air pollution status. There are six pollutants that have NAAQS: particulate matter (formerly as total suspended particulate (TSP) and now as PM_{10} which emphasizes the smaller particles), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3) and lead (Pb). It is important to note that the discussions of ozone in this report refer to ground level, or tropospheric, ozone and not to stratospheric ozone. Ozone in the stratosphere, miles above the earth, is a beneficial screen from the sun's ultraviolet rays. Ozone at ground level, in the air we breathe, is a health and environmental concern.

The trends in ambient air quality that follow are presented as boxplots, which display the 5th, 10th, 25th, 50th (median), 75th, 90th and 95th percentiles of the data, as well as the composite average. The 5th, 10th and 25th percentiles depict the "cleaner" sites, while the 75th, 90th and 95th depict the "higher" sites and the median and average describe the "typical" sites. For example, the 90th percentile means that 90 percent of the sites had concentrations less than or equal to that value, and only 10 percent of the sites had concentrations that were higher. Boxplots simultaneously illustrate trends in the "cleaner", "typical" and "higher" sites.



The ambient air quality trends presented in this report are based upon actual direct measurements. These air quality trends are supplemented with trends for nationwide emissions, which are based upon the best available engineering calculations. Chapter 4 of this report includes a detailed listing of selected 1988 air quality summary statistics for every metropolitan statistical area (MSA) in the nation and maps highlighting the largest MSAs. Chapter 5 presents 1979-88 trends for 15 cities.

1.2 MAJOR FINDINGS

PARTICULATE MATTER

AIR QUALITY

Total Suspended Particulates (TSP)
1979-88: geometric mean: 20 percent decrease (1750 sites)
1984-88: geometric mean: less than 1 percent decrease (1491 sites)
1987-88: geometric mean: 2 percent increase (1491 sites)

PM_{10}
1987-88: arithmetic mean: 4 percent decrease (119 sites)

EMISSIONS (TSP)

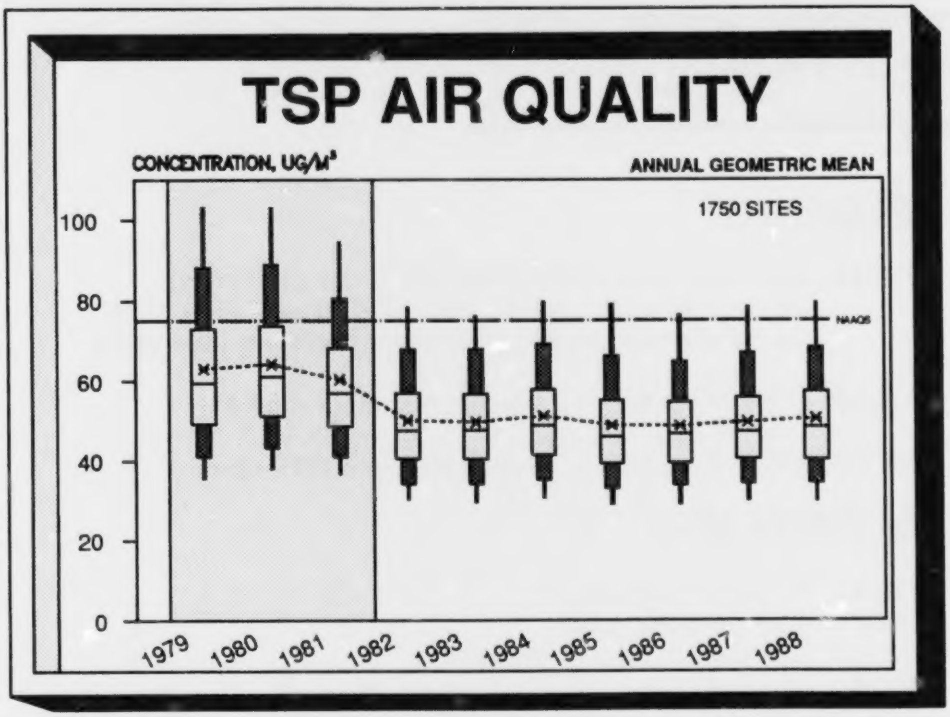
1979-88: 22 percent decrease
1984-88: 7 percent decrease
1987-88: 1 percent decrease

COMMENTS

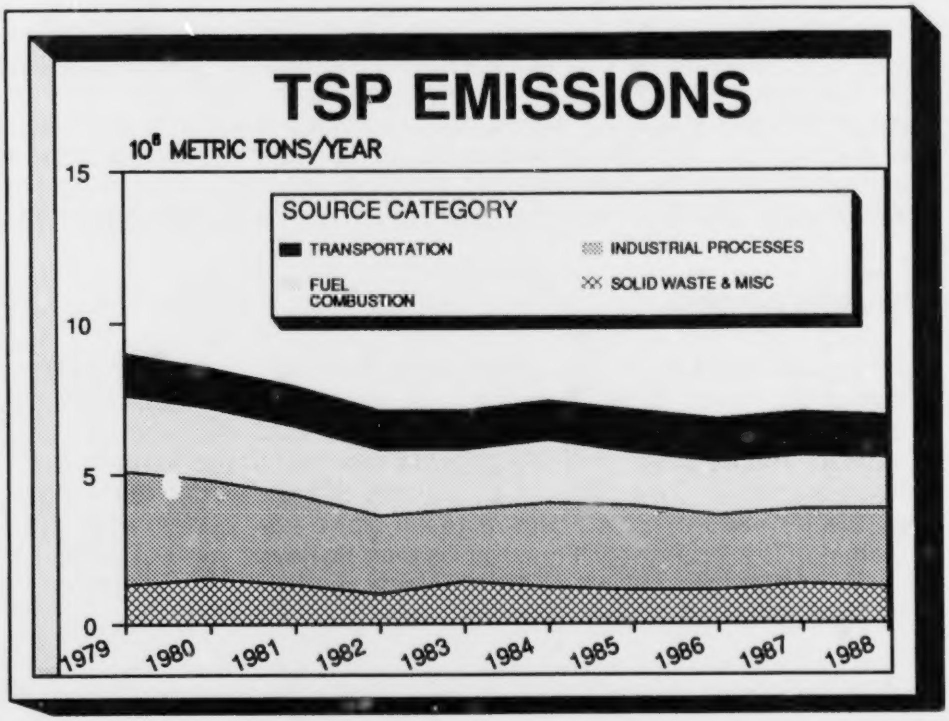
Although the 1979-81 TSP data were affected by a change in sampling filters, average 1978 and 1979 TSP levels differed by only 1 percent. The 1978 data were not affected by the filter change and are comparable to the 1982 and later data. Therefore, the net changes presented above are essentially correct. The 1988 TSP emission estimate may be low because 1988 forest fire emissions data are not yet complete. The PM_{10} network is still evolving and the western U.S. is not fully represented in the 1987-88 data base. The PM_{10} decrease between 1987 and 1988, in contrast to the TSP increase, may indicate that the extremely dry weather in 1988 had more impact on the larger (TSP) particles.

WORTH NOTING

The PM_{10} NAAQS replaced EPA's earlier TSP standard in 1987. PM_{10} focuses on those particles with aerodynamic diameters smaller than 10 micrometers, which are likely to be responsible for adverse health effects because of their ability to reach the lower regions of the respiratory tract. TSP was typically measured every sixth day and only 5 percent of the sites sampled more frequently. In contrast, 25 percent of the PM_{10} monitors sample more frequently.



TSP AIR QUALITY



TSP EMISSIONS

SULFUR DIOXIDE (SO_2)

AIR QUALITY

1979-88: arithmetic mean: 30 percent decrease (374 sites)
24-hour second high: 36 percent decrease (364 sites)
24-hour exceedances: 90 percent decrease (364 sites)

1984-88: arithmetic mean: 13 percent decrease (584 sites)

1987-88: arithmetic mean: 1 percent increase (584 sites)

EMISSIONS (SOx)

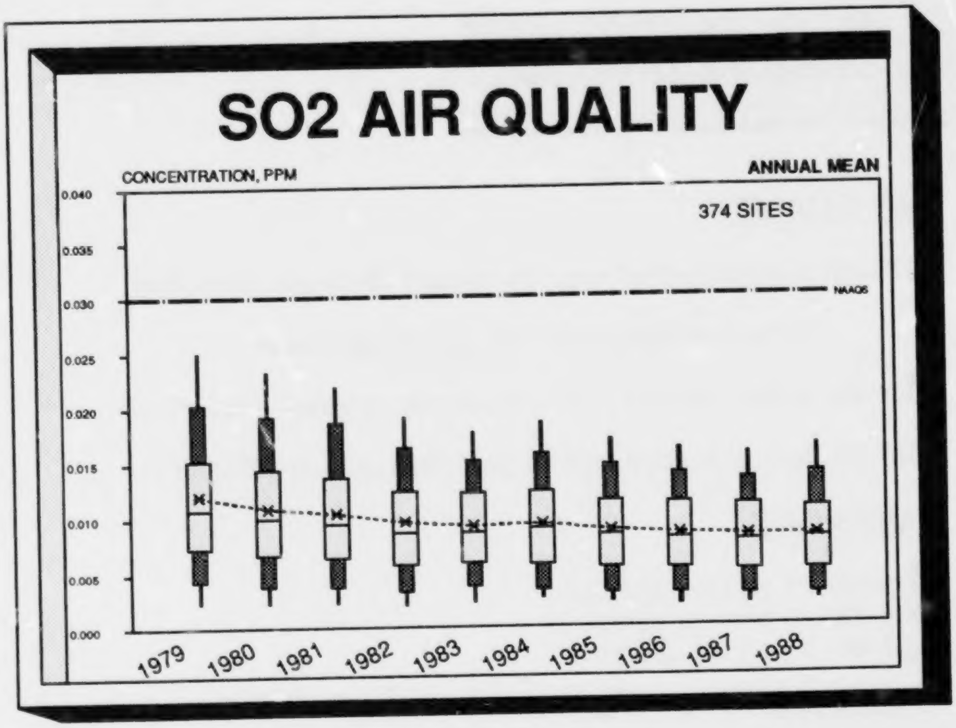
1979-88: 17 percent decrease
1984-88: 4 percent decrease
1987-88: less than 1 percent increase

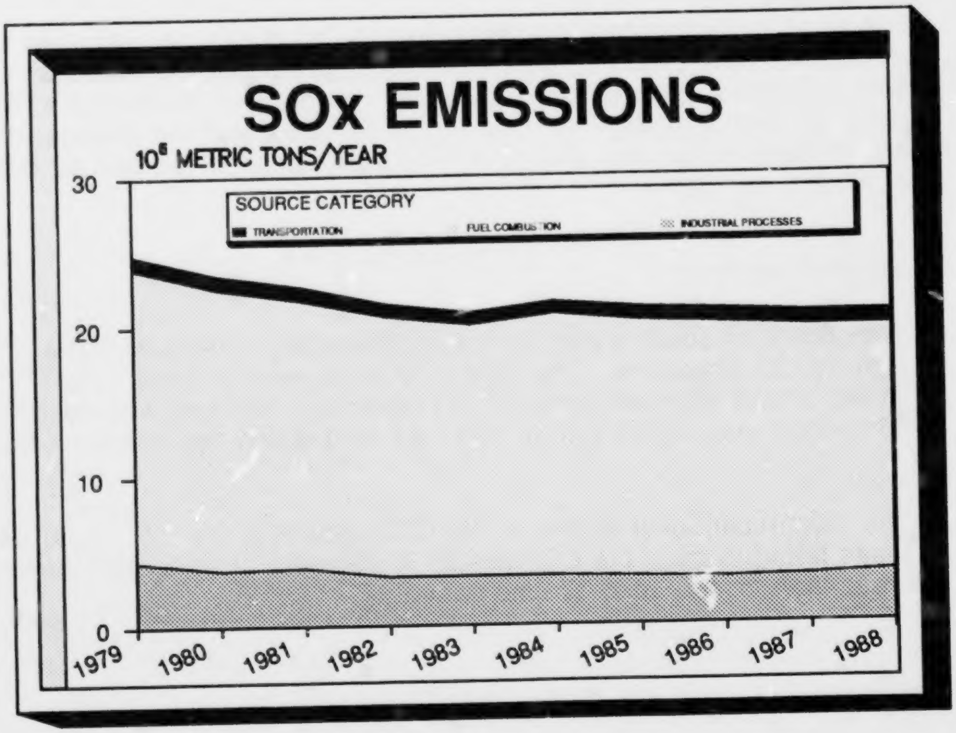
COMMENTS

The vast majority of SO_2 monitoring sites do not show any exceedances of the 24-hour NAAQS and the exceedance trend is dominated by source oriented sites. The increase in sulfur oxides emissions between 1987 and 1988 is due to increased industrial activity, which offset continued reductions in emissions from fuel combustion. The difference between the air quality trends and the emission trends result from the historical ambient monitoring networks being population-oriented while the major emission sources tend to be in less populated areas.

WORTH NOTING

Almost all monitors in U.S. urban areas meet EPA's ambient SO_2 standards, which apply to ground level concentrations. Current concerns about sulfur dioxide focus on major emitters, total atmospheric loadings, and the possible need for a shorter-term (i.e. 1-hour) standard. Two-thirds of all national SO_x emissions are generated by electric utilities (93 percent of which come from coal fired power plants). The majority of these emissions, however, are produced by a small number of facilities. Fifty individual plants in 15 states account for one-half of all power plant emissions.


SO2 AIR QUALITY
CONCENTRATION, PPM
ANNUAL MEAN
374 SITES
NAAQS
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988


SOx EMISSIONS
10^6 METRIC TONS/YEAR
SOURCE CATEGORY
TRANSPORTATION
FUEL COMBUSTION
INDUSTRIAL PROCESSES
30
20
10
0
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988

CARBON MONOXIDE (CO)

AIR QUALITY

1979-88: 8-hour second high: 28 percent decrease (248 sites)

8-hour exceedances: 88 percent decrease

1984-88: 8-hour second high: 16 percent decrease (359 sites)

1987-88: 8-hour second high: 3 percent decrease (359 sites)

EMISSIONS

1979-88: 25 percent decrease
1984-88: 15 percent decrease
1987-88: 5 percent decrease

COMMENTS

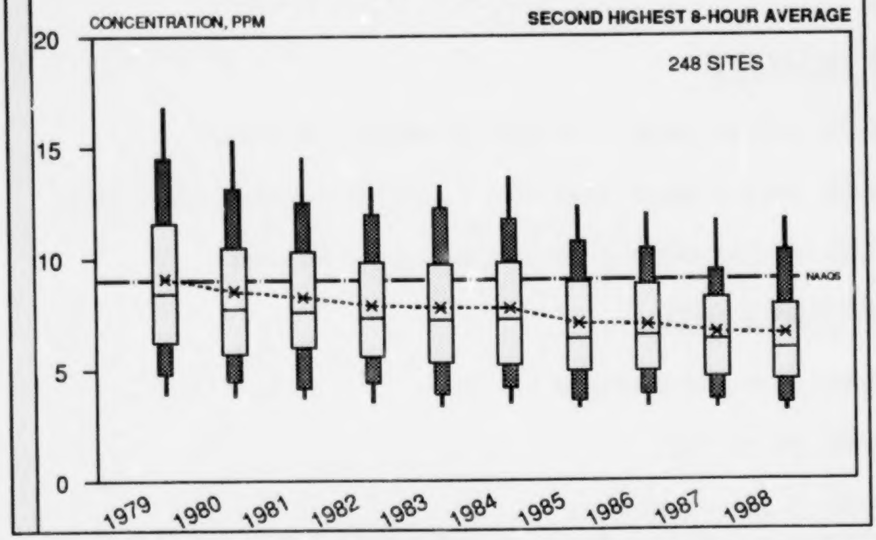
While there is general agreement between the air quality and emission changes over this 10-year period, it should be recognized that the emission changes reflect estimated national totals while the ambient CO monitors are frequently located to identify problems. The mix of vehicles and the change in vehicle miles of travel in an area around a typical CO monitoring site may differ from the national averages.

WORTH NOTING

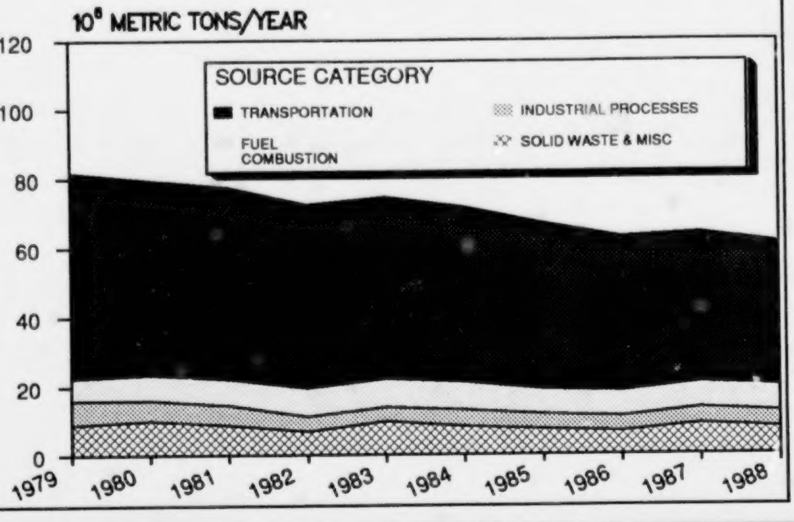
Transportation sources account for approximately two-thirds of the nation's CO emissions. The 1979-88 improvement in ambient CO levels, and in estimated national CO emissions, has occurred despite a 33 percent increase in vehicle miles traveled during this 10-year period.

The most recent assessment of the CO problem in the U.S. found 44 areas failing to meet the CO NAAQS in 1987-88. This is eight fewer areas than for the 1986-87 time period.

CO AIR QUALITY



CO EMISSIONS



NITROGEN DIOXIDE (NO_2)

AIR QUALITY

1979-88: Annual Mean: 7 percent decrease (116 sites)

1984-88: Annual Mean: Less than 1 percent increase (194 sites)

1987-88: Annual Mean: 1 percent increase (194 sites)

EMISSIONS (NOx)

1979-88: 8 percent decrease

1984-88: no change

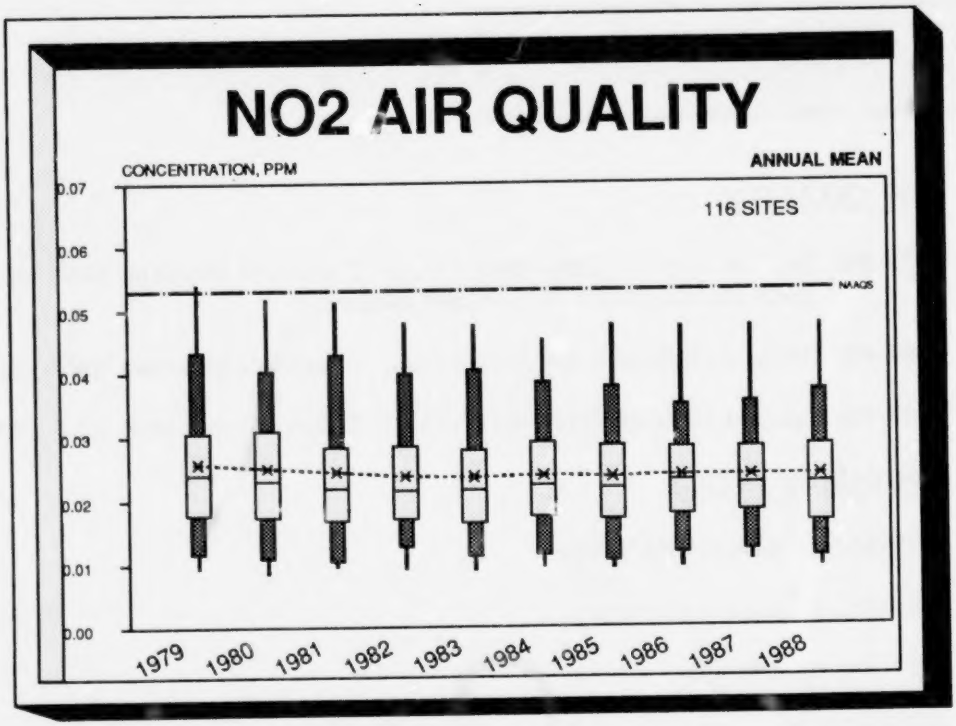
1987-88: 3 percent increase

COMMENTS

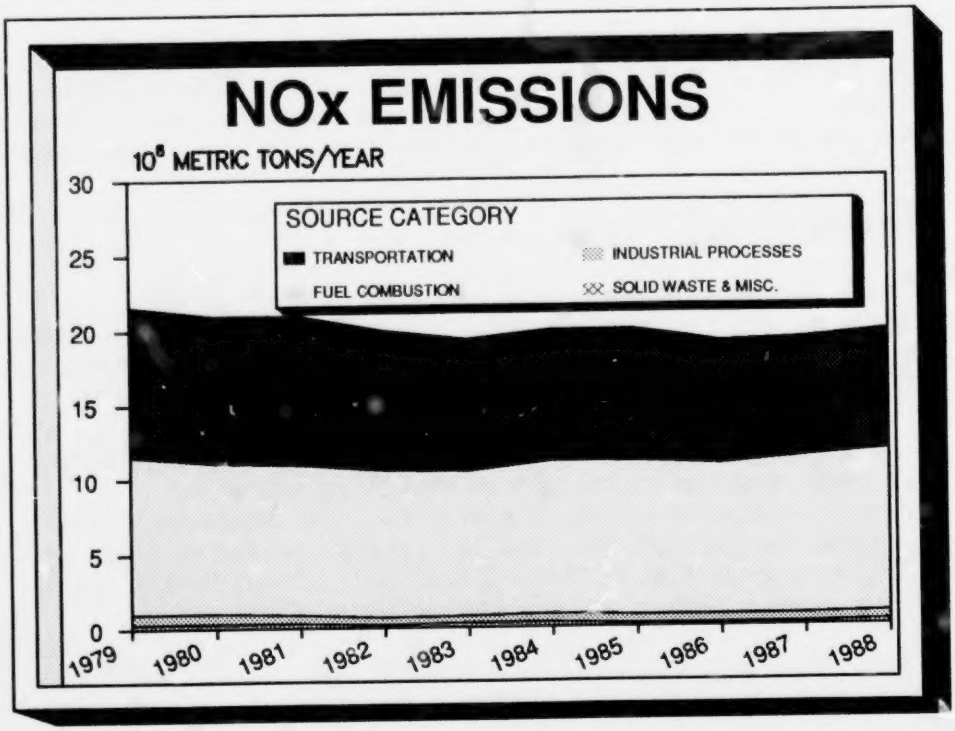
The recent national trend in annual mean NO_2 concentration continues to be flat. The two primary source categories of nitrogen oxide emissions, and their contribution in 1988, are fuel combustion (55 percent) and transportation (41 percent).

WORTH NOTING

Los Angeles, which reported an annual mean of 0.061 ppm in 1988, is the only urban area that has recorded violations of the annual NO_2 NAAQS of 0.053 ppm during the past 10 years.



NO2 AIR QUALITY



NOx EMISSIONS

OZONE (O_3)

AIR QUALITY

1979-88: Second Highest Daily Max 1-hour: 2 percent increase (388 sites)
Exceedance Days: 10 percent decrease

1984-88: Second Highest Daily Max 1-hour: 9 percent increase (567 sites)

1987-88: Second Highest Daily Max 1-hour: 8 percent increase (567 sites)

Emissions (VOC)

1979-88: 17 percent decrease

1984-88: 8 percent decrease

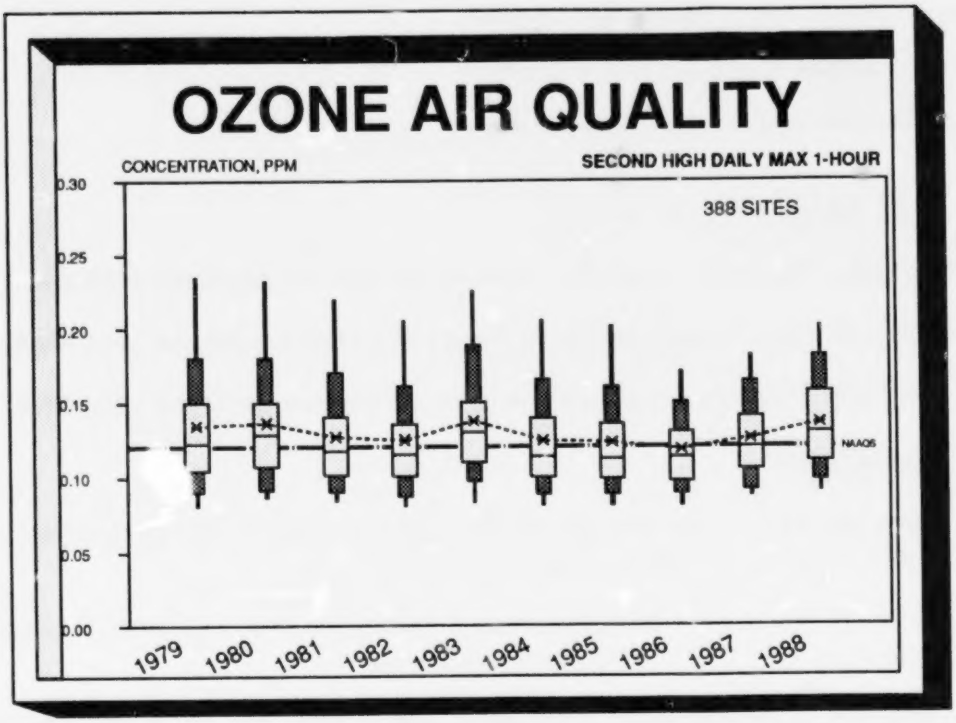
1987-88: no change

COMMENTS

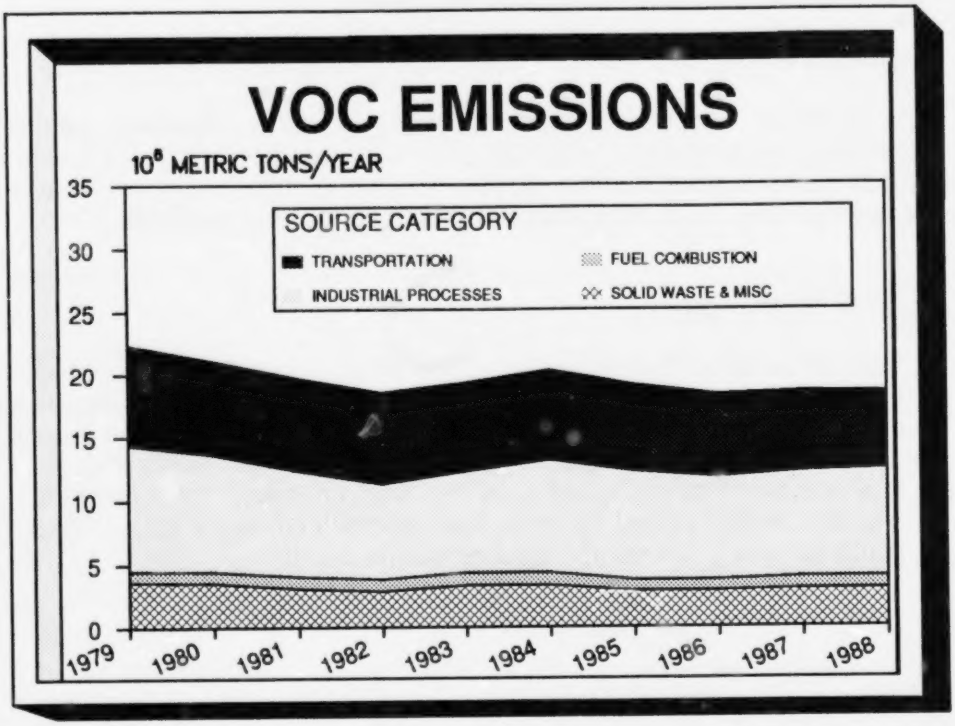
The volatile organic compound (VOC) emission estimates represent annual totals. While these are the best national numbers now available, ozone is predominantly a warm weather problem and seasonal emission trends would seem preferable. New emission inventories will consider this seasonal effect.

WORTH NOTING

Ozone continues to be the most pervasive ambient air pollution problem in the U.S. with 101 areas failing to meet the ozone NAAQS for 1986-88. Recent trends have been affected by weather conditions. The warm 1988 summer was conducive to ozone formation while preliminary data suggests that a cooler, wetter 1989 resulted in lower ozone levels. Just as last year's report indicated that interpretation of the 1988 increases should be tempered by an awareness of the effect of weather conditions, interpretation of the likely decreases in 1989 warrants the same caution. The key point is not whether levels in 1989 were lower than in 1988 but how likely it is for the high ozone levels seen in 1980, 1983, and 1988 to recur.



OZONE AIR QUALITY



VOC EMISSIONS

LEAD (Pb)

AIR QUALITY

1979-88: Maximum Quarterly Average: 89 percent decrease (139 sites)

1984-88: Maximum Quarterly Average: 76 percent decrease (343 sites)

1987-88: Maximum Quarterly Average: 15 percent decrease (343 sites)

Emissions

1979-88: 93 percent decrease in total lead emissions - 97 percent decrease in lead emissions from transportation sources.

1984-88: 81 percent decrease in total lead emissions - 93 percent decrease in lead emissions from transportation sources.

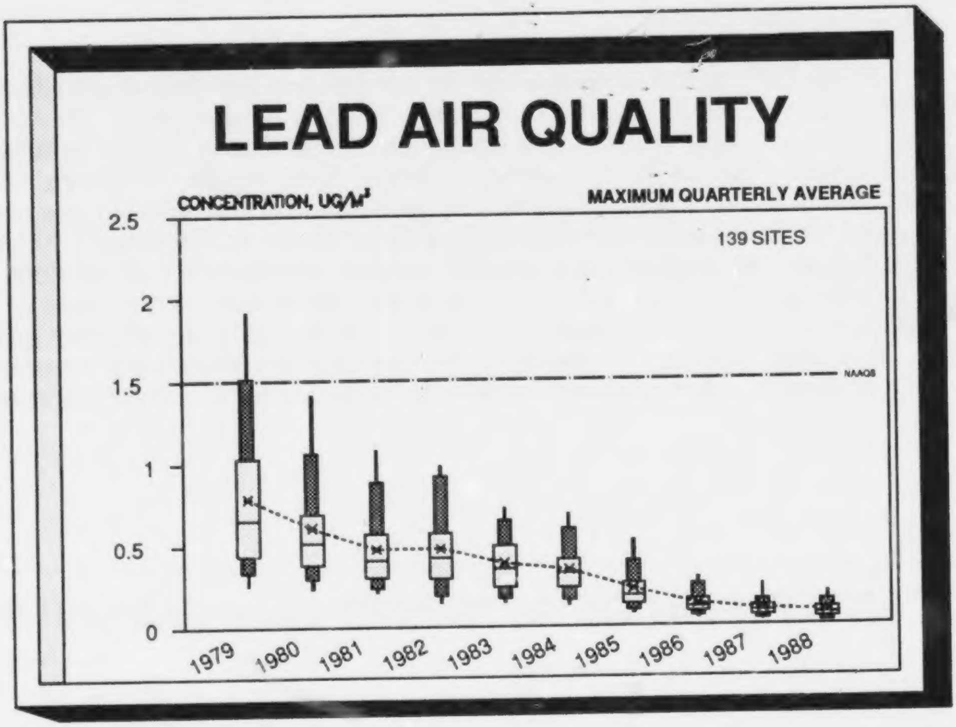
1987-88: 5 percent decrease in total lead emissions - 13 percent decrease in lead emissions from transportation sources.

COMMENTS

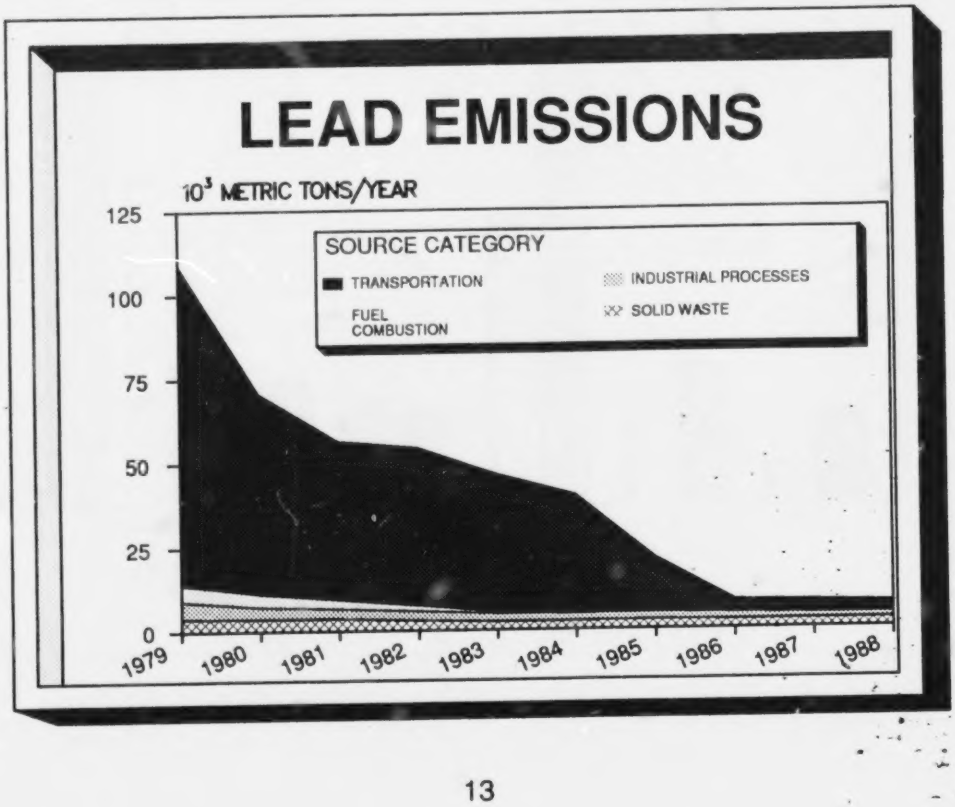
The ambient lead trends presented here primarily represent general urban conditions predominantly reflecting automotive sources. Ambient trends are also presented for a small number of lead monitoring sites (18) in the vicinity of point sources of lead such as primary and secondary lead smelters.

WORTH NOTING

Ambient lead concentrations in urban areas throughout the country have shown major improvements because of both the increased usage of unleaded gasoline and the reduction of the lead content in leaded gasoline. Unleaded gasoline sales accounted for 82 percent of the total gasoline market in 1988. While lead emissions from industrial sources have dropped by more than one-half since the late 1970's, some serious point source lead problems remain.



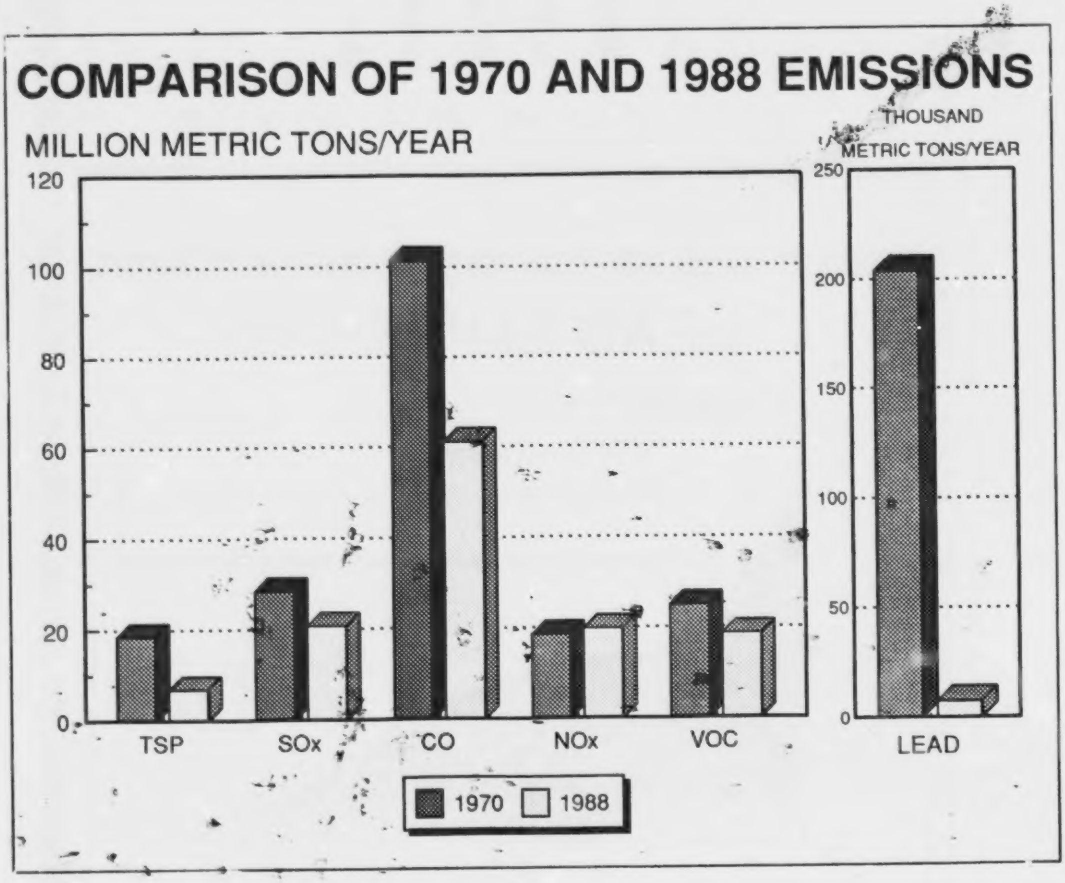
LEAD AIR QUALITY



LEAD EMISSIONS

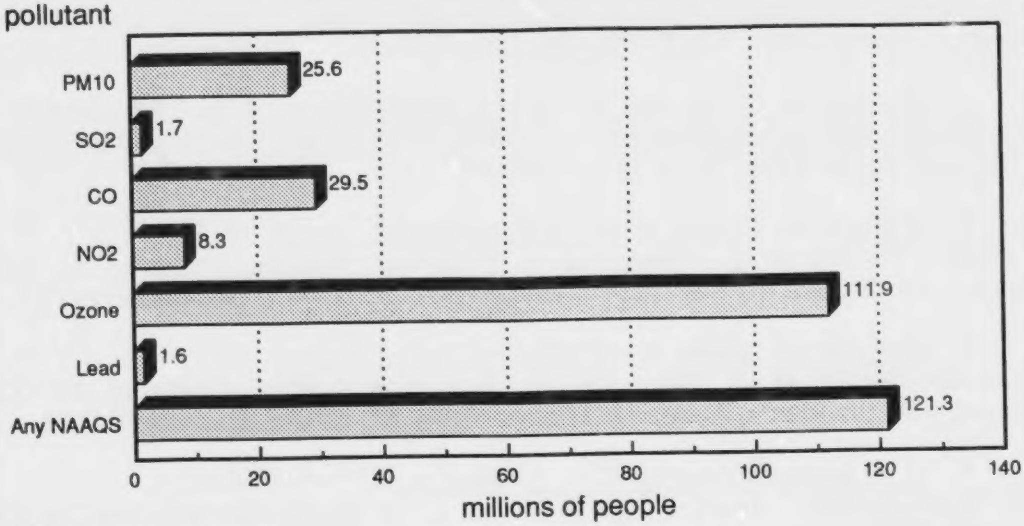
1.3 SOME PERSPECTIVE

A 10-year time period is convenient for considering ambient air pollution trends because monitoring networks underwent many changes around 1980. However, it is important not to overlook some of the earlier control efforts in the air pollution field. Emission estimates are useful in examining longer term trends. Between 1970 and 1988, lead clearly shows the most impressive decrease (-96 percent) but improvements are also seen for total suspended particulate (-63 percent), sulfur oxides (-27 percent), carbon monoxide (-40 percent), and volatile organic compounds (-26 percent). Only nitrogen oxides did not show improvement with emissions estimated to have increased 7 percent, due primarily to increased fuel combustion by stationary sources and motor vehicles. It is also important to realize that many of these reductions occurred even in the face of growth. More detailed information is contained in a companion report.[16]



While it is important to recognize that progress has been made, it is also important not to lose sight of the magnitude of the air pollution problem that still remains. About 121 million people in the U.S. reside in counties which did not meet at least one air quality standard during 1988 and it is apparent why ground level ozone is viewed as our most pervasive ambient air pollution problem. The 112 million people living in counties that exceeded the ozone standard in 1988 are greater than the total for the other five pollutants. These statistics, and associated qualifiers and limitations, are discussed in Chapter 4. As noted, 1988 ozone levels were higher in some areas due to the warm 1988 summer but even in 1987 there were 96.2 million people living in counties that exceeded the ozone NAAQS (based on 1986 population data).

People in counties with 1988 air quality above primary National Ambient Air Quality Standards.



NOTE: Based on 1986 population data.

Finally, it should be recognized that this report focuses on what may be viewed as the traditional air pollutants for which an established data base exists. As our knowledge increases, we are becoming more aware of additional air pollution concerns that warrant attention and, in many cases, we are learning of the increasing complexity involved in solving existing problems.

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2. INTRODUCTION

This report focuses on both 10-year (1979-88) and 5-year (1984-88) national air quality trends for each of the major pollutants for which National Ambient Air Quality Standards (NAAQS) have been established, as well as Regional and, where appropriate, short-term air quality trends. This Section presents many of the technical details involved in these analyses; readers familiar with previous reports may prefer initially to proceed directly to the remaining Sections. The national analyses are complemented in Section 5 with air quality trends in 15 metropolitan areas for the period 1979 through 1988. The areas examined are Atlanta, GA; Baltimore, MD; Boston, MA; Chicago, IL-Northwestern IN; Denver, CO; Detroit, MI; Houston, TX; Los Angeles-Long Beach, CA; New York, NY-Northeastern NJ; Philadelphia, PA-NJ; Phoenix, AZ; Portland, OR-WA; St. Louis, MO-IL; Seattle, WA; and Washington, DC. Due to limited 10-year data records, a 5-year period 1984-88 was used in some cases.

The national air quality trends are presented for all sites and for the National Air Monitoring Station (NAMS) sites. The NAMS were established through monitoring regulations promulgated in May 1979[1] to provide accurate and timely data to the U.S. Environmental Protection Agency (EPA) from a national air monitoring network. The NAMS are located in areas with higher pollutant concentrations and high population exposure. These stations meet uniform criteria for siting, quality assurance, equivalent analytical methodology, sampling intervals, and instrument selection to assure consistent data reporting among the States. Other sites operated by the State and local air pollution control agencies, such as the State and Local Air Monitoring Stations (SLAMS) and Special Purpose Monitors (SPM), in general, also meet the same rigid criteria, except that in addition to being located in the area of highest concentration and high population exposure, they are located in other areas as well. The ambient levels presented are the results of direct air pollution measurements.

Trends are also presented for annual nationwide emissions. These are estimates of the amount and kinds of pollution being emitted by automobiles, factories, and other sources, based upon the best available engineering calculations for a given time period. The emission trends are taken from the EPA publication, National Air Pollutant Emission Estimates, 1940-1988[2] and the reader is referred to this publication for more detailed information. For particulates, emission estimates are intended to represent total particulate emissions without any distinction of particle sizes. Area source fugitive dust emissions (unpaved roads, construction activities, etc.) are not included at all. Similarly, natural sources of particulates, such as wind erosion or dust, are not included. (Forest fires, some of which result from natural causes are included, however). In total, these fugitive emissions may amount to a considerable portion of total particulate emissions. For CO, VOC and NO_x, emission estimates for gasoline- and diesel-powered motor vehicles were based upon vehicle-mile tabulations and emission factors from the MOBILE 4.0 model.

Air quality status may be determined by comparing the ambient air pollution levels with the appropriate primary and secondary National Ambient Air Quality Standards (NAAQS) for each of the pollutants (Table 2-1). Primary standards protect the public health; secondary standards protect the public welfare as measured by effects of pollution on vegetation, materials, and visibility. The standards are further categorized for different averaging times. Long-term standards specify an annual or quarterly mean that may not be exceeded; short-term standards specify upper limit values for 1-, 3-, 8-, or 24-hour averages. With the exception of the pollutants ozone and PM_{10}, the short-term standards are not to be exceeded more than once per year. The ozone standard requires that the expected number of days per calendar year with daily maximum hourly concentrations exceeding 0.12 parts per million (ppm) be less than or equal to one. The 24-hour PM_{10} standard also allows one expected exceedance per year.

Section 4 of this report, "Air Quality Levels in Metropolitan Statistical Areas" provides greatly simplified air pollution information. Air quality statistics are presented for each of the pollutants for all MSAs reporting monitoring data to EPA for 1988.

During Summer 1989, EPA continued the cooperative program with the State and local air pollution agencies for the accelerated reporting of preliminary ozone data from a subset of peak monitoring sites. These data have been merged with the trends data base to provide a preliminary assessment of 1989 ozone trends.

2.1 DATA BASE

The ambient air quality data used in this report were obtained from EPA's Aerometric Information and Retrieval System (AIRS). Air quality data are submitted to AIRS by both State and local governments, as well as federal agencies. At the present time, there are about 500 million air pollution measurements on AIRS, the vast majority of which represent the more heavily populated urban areas of the nation.

Previously[3], the size of the available air quality trends data base was expanded by merging data at sites which had experienced changes in the agency operating the site, the instruments used, or in the project codes, such as a change from population oriented to special purpose monitoring. In contrast to the old Storage and Retrieval of Aerometric Data (SAROAD) System, which created separate records in these cases, the pollutant occurrence code (POC) was established in AIRS to create combined summary records for these monitoring situations. However, in the case of Pb, the previous procedure of merging data was employed to combine data collected using different sampling intervals.

In order for a monitoring site to have been included in the national 10-year trend analysis, the site had to contain data for at least 8 of the 10 years 1979 to 1988. For the national 5-year trend, the site had to contain 4 out of 5 years of data to be included as a trend site. Data for each year had to satisfy annual data completeness criteria appropriate to pollutant and measurement methodology. The air quality data are divided into two major groupings -- 24-hour measurements and continuous 1-hour measurements. The 24-hour measurements are obtained from monitoring instruments that produce one measurement per 24-hour period and are typically operated on a systematic sampling schedule of once every 6 days, or 61 samples per year. Such

TABLE 2-1. National Ambient Air Quality Standards (NAAQS) in Effect in 1988

POLLUTANT	PRIMARY (HEALTH RELATED)		SECONDARY (WELFARE RELATED)	
	AVERAGING TIME	STANDARD LEVEL CONCENTRATION[a]	AVERAGING TIME	CONCENTRATION
PM$_{10}$	Annual Arithmetic Mean[b]	50 µg/m3	Same as Primary	
	24-hour[b]	150 µg/m^3	Same as Primary	
SO$_2$	Annual Arithmetic Mean	(0.03 ppm) 80 µg/m^3	3-hour[c]	1300 µg/m^3 (0.50 ppm)
	24-hour[c]	(0.14 ppm) 365 µg/m^3		
CO	8-hour[c]	9 ppm (10 mg/m^3)	No Secondary Standard	
	1-hour[c]	35 ppm (40 mg/m^3)	No Secondary Standard	
NO$_2$	Annual Arithmetic Mean	0.053 ppm (100 µg/m^3)	Same as Primary	
O$_3$	Maximum Daily 1-hour Average[d]	0.12 ppm (235 µg/m^3)	Same as Primary	
Pb	Maximum Quarterly Average	1.5 µg/m^3	Same as Primary	

[a] Parenthetical value is an approximately equivalent concentration.

[b] TSP was the indicator pollutant for the original particulate matter (PM) standards. This standard has been replaced with the new PM$_{10}$ standard and it is no longer in effect. New PM standards were promulgated in 1987, using PM$_{10}$ (particles less than 10µ in diameter) as the new indicator pollutant. The annual standard is attained when the expected annual arithmetic mean concentration is less than or equal to 50 µg/m^3; the 24-hour standard is attained when the expected number of days per calendar year above 150 µg/m^3 is equal to or less than 1; as determined in accordance with Appendix K of the PM NAAQS.

[c] Not to be exceeded more than once per year.

[d] The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than 1, as determined in accordance with Appendix H of the Ozone NAAQS.

instruments are used to measure TSP, PM_{10}, SO_2, NO_2 and Pb. For PM_{10}, more frequent sampling of every other day or everyday is now also common. Bubbler data were not used in the SO_2 and NO_2 trends analyses because these methods have essentially been phased out of the monitoring network. Total suspended particulate and PM_{10} data were judged adequate for trends if there were at least 30 samples for the year. Both 24-hour and composite data were used in the Pb trends analyses. The 24-hour Pb data had to have at least six samples per quarter in at least 3 of the 4 calendar quarters. Monthly composite Pb data were used if at least two monthly samples were available for at least 3 of the 4 calendar quarters.

The 1-hour data are obtained from monitoring instruments that operate continuously, producing a measurement every hour for a possible total of 8760 hourly measurements in a year. For continuous hourly data, a valid annual mean for SO_2 and NO_2 trends requires at least 4380 hourly observations. This same annual data completeness, of at least 4380 hourly values, was required for the CO standard related statistics - the second maximum nonoverlapping 8-hour average and the estimated number of exceedances of the 8-hour average CO standard. A slightly different criterion was used for the SO_2 standard related daily statistics - the second daily maximum 24-hour average and the estimated number of daily exceedances of the SO_2 standard. Instead of requiring 4380 or more hourly values, 183 or more daily values were required. A valid day is defined as one consisting of at least 18 hourly observations. This produces a slightly different data base of sites used in the national analysis for the daily SO_2 statistics.

Finally, because of the seasonal nature of ozone, both the second daily maximum 1-hour value and the estimated number of exceedances of the 0_3 NAAQS were calculated for the ozone season, which typically varies by State.[4] For example, in California, the ozone season is defined as 12 months, January through December, while in New Jersey it is defined as 7 months, April through October. In order for a site to be included, at least 50 percent of its daily data had to be available for the ozone season. For all pollutants, the site must satisfy the annual completeness criteria, specified above in at least 8 out of 10 years for it to be included in the 10-year air quality trends data base, and 4 out of 5 years to be included in the 5-year trend data base. Table 2-2 displays the number of sites meeting the completeness criteria for both trends data bases.

The use of moving 10-year and 5-year windows for trends yields a data base that is more consistent with the current monitoring network. In addition, this procedure increased the total number of trend sites by 11 percent for the 10-year period, but increased by less than 1 percent for the 5-year period relative to the data bases used in the last annual report.[5] The reader should note that the size of the TSP monitoring network has been declining, especially since promulgation of the PM_{10} standard. This decline in the number of TSP sites between the 10-year and 5-year data bases results from the difference in the number of years required for the two time periods. If a site discontinued operation in 1987, it would be included in the 10-year data base, but not in the 5-year data base (since 2 of the 5 years would be missing). In general, the data from the post 1980 period should be of the highest quality. Focusing on the non-TSP sites in Table 2-2, there is a 62% increase in the number of sites in the 5-year data base as compared to the 10-year period. Except for NO_2, trend sites can be found in all EPA Regions (Figure 2-1) for TSP, SO_2, CO, O_3 and Pb for the 5-year period.

2.2 TREND STATISTICS

The air quality analyses presented in this report comply with the recommendations of the Intra-Agency Task Force on Air Quality Indicators.[6] This task force was established in January 1980 to recommend standardized air quality indicators and statistical methodologies for presenting air quality status and trends. The Task Force report was published in February 1981. The air quality statistics used in these pollutant-specific trend analyses relate to the appropriate NAAQSs. Two types of standard-related statistics are used - peak statistics (the second maximum 24-hour SO_2 average, the second maximum nonoverlapping 8-hour CO average, and the second daily maximum 1-hour 0_3 average) and long-term averages (the annual geometric mean for TSP, the annual arithmetic means for PM_{10}, SO_2 and NO_2, and the quarterly arithmetic mean for Pb). In the case of the peak statistics, the second maximum value is used, because this is the value which traditionally has been used to determine whether or not a site has or has not met an air quality standard in a particular year. For PM_{10}, with its variable sampling frequency, the 90th percentile of 24-hour concentrations is used to examine changes in peak values. A composite average of each of these statistics is used in the graphical presentations which follow. All sites were weighted equally in calculating the composite average trend statistic. Missing annual summary statistics for the second through ninth years for a site are estimated by linear interpolation from the surrounding years. Missing end points are replaced with the first valid year of data. This procedure results in a statistically balanced data set to which simple statistical procedures can be applied. The procedure is also conservative, because end-point rates of change are dampened by the interpolated estimates.

The air quality trends information in Section 3 is presented using trend lines, confidence intervals, boxplots[7] and bar graphs. This report presents statistical confidence intervals to facilitate a better understanding of measured changes in air quality. Confidence intervals are placed around composite averages, which are based on sites that satisfy annual data completeness requirements. The confidence intervals can be used to make comparisons between years; if the confidence intervals for any 2 years do not overlap, then the composite averages of the 2 years are significantly different (Figure 2-2). Ninety-five percent confidence intervals for composite averages of annual means (arithmetic and geometric) and second maxima were calculated from a two-way analysis of variance followed by an application of the Tukey Studentized Range.[8] The confidence intervals for composite averages of estimated exceedances were calculated by fitting Poisson distributions[9] to the exceedances each year and then applying the Bonferroni multiple comparisons procedure.[10] The utilization of these procedures is explained in publications by Pollack, Hunt and Curran[11] and Pollack and Hunt.[12]

Table 2-2. Number of Sites for 10-Year and 5-Year Air Quality Trends

	NUMBER OF TREND	
SITES POLLUTANT	1979-88	1984-88
Total Suspended Particulate (TSP)	1750	1491
Sulfur Dioxide (SO_2)	374	584
Carbon Monoxide (CO)	248	359
Nitrogen Dioxide (NO_2)	116	194
Ozone (0_3)	388	567
Lead (Pb)	139	343
Total	3015	3538

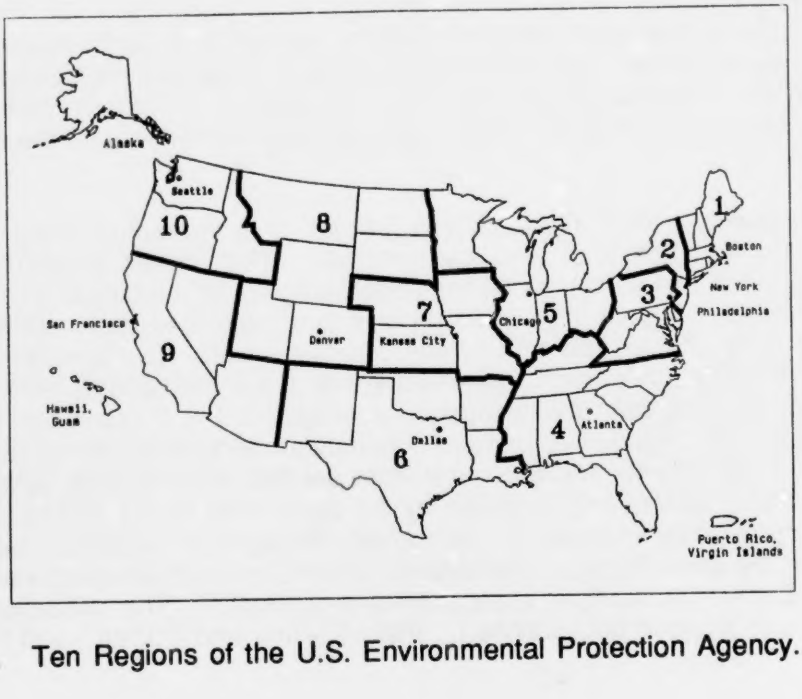
Alaska
Seattle
10
8
1
2
Boston
New York
3
Philadelphia
San Francisco
9
Denver
Kansas City
7
Chicago
5
Hawaii,
Guam
4
Atlanta
Dallas
6
Puerto Rico,
Virgin Islands

Figure 2-1. Ten Regions of the U.S. Environmental Protection Agency.

A recent study examined the procedure for estimating the national means and accompanying confidence intervals.[13] A general linear model (GLM) approach to estimating national averages without interpolating missing site-years was developed and evaluated. The GLM approach was applied to the ozone and total suspended particulate trends data bases from last years' report.[5] The TSP data set was chosen for analysis because it was the pollutant with the largest number of monitoring sites. The ozone data set was chosen, on the other hand, because it was expected to reveal the largest differences between the two methods, as ozone is highly variable from year to year. In the case of TSP, four of the ten composite means were the same value, and the remaining six means differed by only 0.1 ug/m^3 (less than one-half of one percent) between the two approaches. For ozone, the estimated national composite ozone averages were within 0.001 ppm in all cases but one. The single exception was the 1978 composite average where the GLM estimate was 6 percent higher than the traditional estimate. The size of this difference is likely due to the unusually high number of missing sites (45 percent) for that year. Recall that the promulgation of the monitoring regulations in 1979 precipitated network revisions, with greater network stability since 1979.

The GLM approach is not appropriate for estimating missing exceedance counts. However, work is continuing on developing an alternative approach for exceedances and on integrating the GLM approach into the trends analysis procedures.

Boxplots are used to present air quality trends because they have the advantage of displaying, simultaneously, several features of the data. Figure 2-3 illustrates the use of this technique in presenting the 5th, 10th, 25th, 50th (median), 75th, 90th and 95th percentiles of the data, as well as the composite average. The 5th, 10th and 25th percentiles depict the "cleaner" sites. The 75th, 90th and 95th depict the "higher" sites, and the median and average describe the "typical" sites. For example, 90 percent of the sites would have concentrations equal to or lower than the 90th percentile. Although the average and median both characterize typical behavior, the median has the advantage of not being affected by a few extremely high observations. The use of the boxplots allows us simultaneously to compare trends in the "cleaner", "typical" and "higher" sites.

Bar graphs are introduced for the Regional comparisons with the 5-year trend data base. The composite averages of the appropriate air quality statistic of the years 1986, 1987 and 1988 are presented. The approach is simple, and it allows the reader at a glance to compare the short-term trends in all ten EPA Regions.

In addition to concentration related statistics, other statistics are used, when appropriate, to clarify further the observed air quality trends. Particular attention is given to the estimated number of exceedances of the short-term NAAQSs. The estimated number of exceedances is the measured number of exceedances adjusted to account for incomplete sampling. Trends in exceedances tend to be more variable than in the other concentration related statistics, particularly on a percentage basis. For example, a site may show a 50 percent decrease in annual exceedances, from 2 to 1 per year, and yet record less than a 5 percent decrease in average concentration levels. The change in concentration levels is likely to be more indicative of changes in emission levels.

For a pollutant such as ozone, for which the level of the standard was revised in 1979, exceedances for all years were computed using the most recent level of the standard. This was done to ensure that the trend in exceedances is indicative of air quality trends rather than of a change in the level of the standard.

Trends are also presented for annual nationwide emissions. These emissions data are estimated using the best available engineering calculations. The emissions data are reported as teragrams (one million metric tons) emitted to the atmosphere per year, with the exception of lead emissions, which are reported as gigagrams (one thousand metric tons).[2] These are estimates of the amount and kinds of pollution being generated by automobiles, factories and other sources. Estimates for earlier years are recomputed using current methodology so that these estimates are comparable over time.

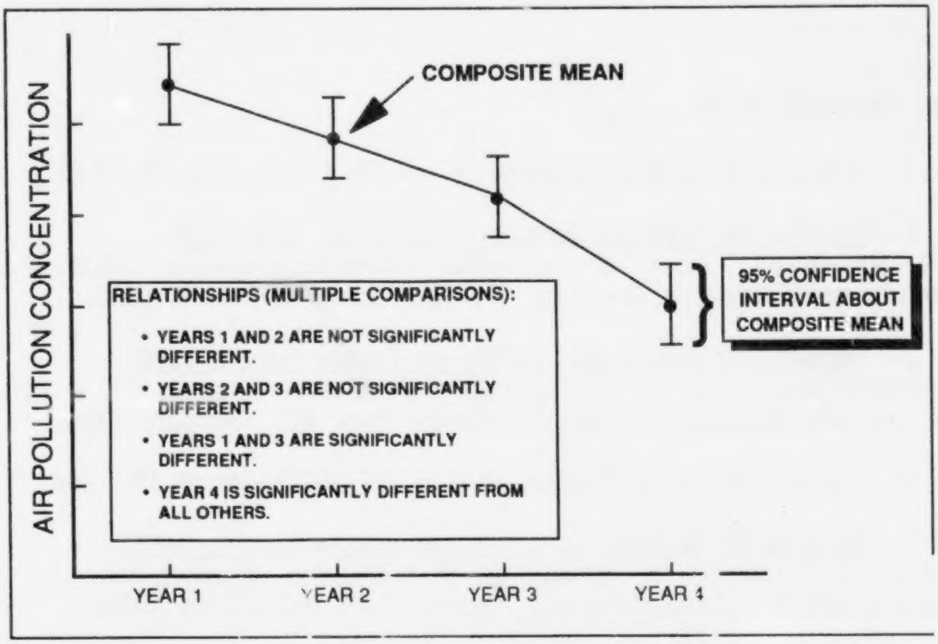

Figure 2-2. Sample illustration of use of confidence intervals to determine statistically significant change.

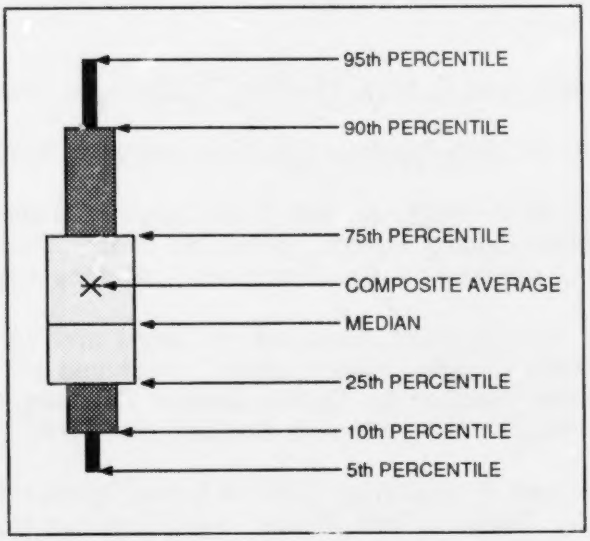
95th PERCENTILE
90th PERCENTILE
75th PERCENTILE
COMPOSITE AVERAGE
MEDIAN
25th PERCENTILE
10th PERCENTILE
5th PERCENTILE

Figure 2-3. Illustration of plotting conventions for boxplots.

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3. NATIONAL AND REGIONAL TRENDS IN NAAQS POLLUTANTS

EPA has set National Ambient Air Quality Standards (NAAQS) for six pollutants considered harmful to public health: particulate matter [formerly as total suspended particulates (TSP), now as particulates less than 10 microns in diameter (PM_{10})], sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3) and lead (Pb). This chapter focuses on both 10-year (1979-88) and 5-year (1984-88) trends, in air quality and emissions for these six pollutants. Changes since 1987, and comparisons between all the trend sites and the subset of National Air Monitoring Stations (NAMS) are highlighted. Trends are examined for both the nation and the 10 EPA Regions.

As in previous reports, the air quality trends are presented using trend lines, confidence intervals, boxplots and bar graphs. The reader is referred to Section 2.2 for a detailed description of the confidence interval and boxplot procedures. The plotting conventions for the confidence intervals and boxplots are shown in Figures 2-2 and 2-3, respectively. Boxplots of all trend sites are presented for each year in the 10-year trend. In the recent 5-year trend, the boxplots are presented for the years 1984 through 1988. The 5-year trend was introduced in the 1984 report to increase the number of sites available for analysis and to make use of data from more recently established sites. The recent 5-year period is presented to take advantage of the larger number of sites, and of sites meeting uniform siting criteria and quality assurance procedures.

Trends are also presented for annual nationwide emissions of particulate matter, sulfur oxides (SO_x), carbon monoxide, nitrogen oxides (NO_x), volatile organic compounds (VOC) and lead. These emissions data are estimated using best available engineering calculations. The reader is referred to a companion report for a detailed description of emission trends, source categories and estimation procedures.[1] For particulates, emission estimates are presented in terms of total particulate matter which include all particles regardless of size. These estimates are comparable to ambient TSP. In the future, trends reports will include particulate matter trends relating to PM_{10} air quality, as data for the necessary engineering calculations are developed.

While the ambient data trends and the emission trends can be viewed as independent assessments that lend added credence to the results, the emission estimates can be used to provide information on trends over longer time periods. Because of changes that have occurred in ambient monitoring measurement methodology and the change over time in the geographical distribution of monitors, it is difficult to provide ambient trends going back to 1970, other than for TSP, which is discussed later, and yet it is important not to lose sight of some of the earlier progress that was made in air pollution control. Emission estimates can provide some insight in this area. Figure 3-1 depicts long-term change in emission estimates. Lead clearly shows the most impressive decrease of 96 percent but improvements are also seen for TSP (-63 percent), SO_x (-27 percent), CO (-40 percent), and VOC (-26 percent). Only NO_x has not shown improvement with emissions estimated to have increased 7 percent, due primarily to increased fuel combustion by stationary sources and motor vehicles.

Because almost all areas meet the current NAAQS for NO_2, it is probably not surprising that the other pollutants are where the emission reductions have occurred.

Because of the continuing interest in ozone levels, EPA continued its 1988 cooperative program with the State and local air pollution agencies for the early reporting of preliminary ozone data. The number of sites was greatly expanded in the 1989 survey, with 588 sites reporting preliminary data. A total of 311 of the 388 sites in the 10-year data base were included in this year's survey. A preliminary estimate of 1989 ozone trends is provided in Section 3.5.

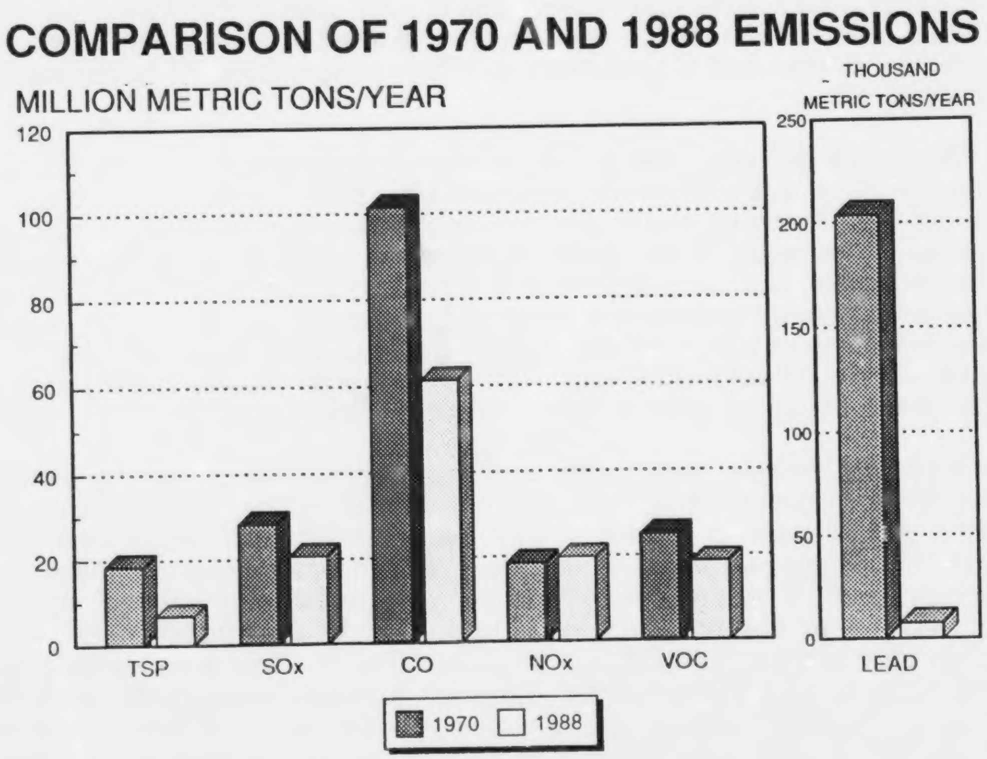

Figure 3-1. Comparison of 1970 and 1988 emissions.

3.1 TRENDS IN PARTICULATE MATTER

Air pollutants called particulate matter include dust, dirt, soot, smoke and liquid droplets directly emitted into the air by sources such as factories, power plants, cars, construction activity, fires and natural windblown dust as well as particles formed in the atmosphere by transformation of emitted gases such as sulfur dioxide and volatile organic compounds.

Annual and 24-hour National Ambient Air Quality Standards (NAAQS) for particulate matter were first set in 1971. Total suspended particulate (TSP) was the indicator used to represent suspended particles in the ambient air. TSP is measured using a high volume sampler (Hi-Vol) which collects suspended particles ranging up to approximately 45 micrometers in diameter.

On July 1, 1987 EPA promulgated new annual and 24-hour standards for particulate matter, using a new indicator, PM_{10}, that includes only those particles with aerodynamic diameter smaller than 10 micrometers. These smaller particles are likely responsible for most adverse health effects of particulate because of their ability to reach the thoracic or lower regions of the respiratory tract. The original (TSP) standards were an annual geometric mean of 75 $\mu g/m^3$, not to be exceeded, and a 24-hour concentration of 260 $\mu g/m^3$, not to be exceeded more than once per year. The new (PM_{10}) standards specify an expected annual arithmetic mean not to exceed 50 $\mu g/m^3$ and an expected number of 24-hour concentrations greater than 150 $\mu g/m^3$ per year not to exceed one.

Now that the standards have been revised, PM_{10} monitoring networks are being deployed nationally. There are basically two types of reference instruments currently used to sample PM_{10}. The first is essentially a Hi-Vol, like the one used for TSP, but with a different size selective inlet (SSI). This sampler uses an inert quartz filter. The other type of instrument is a "dichotomous" sampler. It uses a different PM_{10} inlet, operates at a slower flow rate, and produces two separate samples: 2.5 to 10 microns and less than 2.5 microns, each collected on a teflon filter.

With the new PM_{10} standards, more emphasis is being placed on detection of peak 24-hour concentrations. Unlike monitoring regulations for TSP which only required once in 6 day sampling, new specifications for PM_{10} now dictate more frequent sampling. Approximately one-fourth of all PM_{10} sampling sites operate either every other day or everyday. In contrast, only 5 percent of TSP Hi-Vols operate more frequently than once in 6 days.

Although some monitoring for PM_{10} was initiated prior to promulgation of the new standards, most networks did not produce data with approved reference samplers until 1987 or 1988. Thus, only a limited data base is currently available to examine trends in PM_{10} air quality. Accordingly, particulate matter trends presented in this Section will be based primarily on TSP. Trends for TSP are presented in terms of average air quality (annual geometric mean). In addition, available information on PM_{10} air quality will be used to report the 1987 - 1988 change in PM_{10} concentration levels.

Two PM_{10} statistics are presented. The annual arithmetic mean concentration is used to reflect average air quality, and the 90th percentile of 24-hour concentrations is used to represent the behavior of peak concentrations. Because PM_{10} sampling frequency varies among sites and may have changed during the 2-year period, the 90th percentile is used. This statistic is less sensitive to changes in sampling frequency than the peak values. Finally, cross sectional PM_{10} data is included for the more comprehensive data available for calendar year 1988.

3.1.1 Historical Perspective: 1960-88

TSP data have been collected throughout the nation for over 30 years, and have exhibited substantial declines in pollutant concentration. The most recent 10-year period merely represents the tail end of over 3 decades of improvements resulting from nationwide air pollution control. Historical emission estimates are also available and have also been compiled for this same 30-year period.

The TSP trends are constructed from an evolving network of particulate samplers, and are presented as separate trend lines for each decade. During the 1960's, 122 TSP sampling locations from the relatively limited National Air Surveillance Network (NASN) are used to characterize the early national particulate trend. These early TSP samplers operated on a bi-weekly schedule. With the passage of the Clean Air Act, TSP sampling networks operated by State and local air pollution control agencies developed and typically sampled once in 6 days. The number of operating samplers varied over time, with the national network peaking during the mid-1970's, when almost 4500 sampling stations existed throughout the country. From these stations, 1109 and 1750 sites with sufficient data continuity are used to define the national trend for the 1970's and 1980's, respectively. It should be noted that TSP is the only pollutant with a large national monitoring network, using a consistent sampling methodology which permits this type of trend analysis.

Figure 3-2 reveals that the 3-decade decline in ambient particulate concentrations is reasonably steady, with an obvious leveling off during the 1980's. Although the three trend segments are derived from different sites, they present a nearly continuous record. Year-to-year variability in the composite TSP concentrations during the early years is attributed to the small number of operating samplers. The perturbation from a generally declining trend, which occurred around 1980, is attributed to a change in sampling filters and is discussed in more detail in the next section.

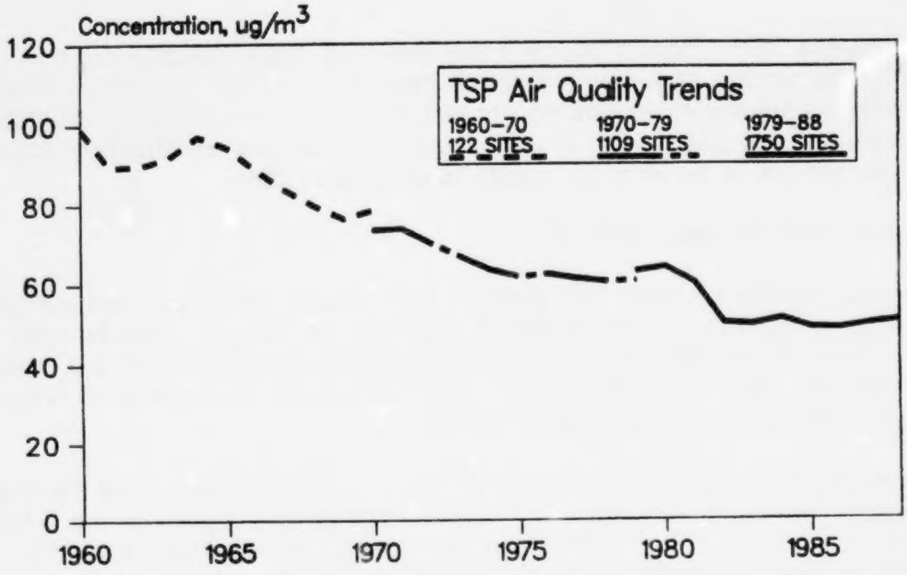

Figure 3-2. Historical trends in ambient TSP concentrations, 1960-1988

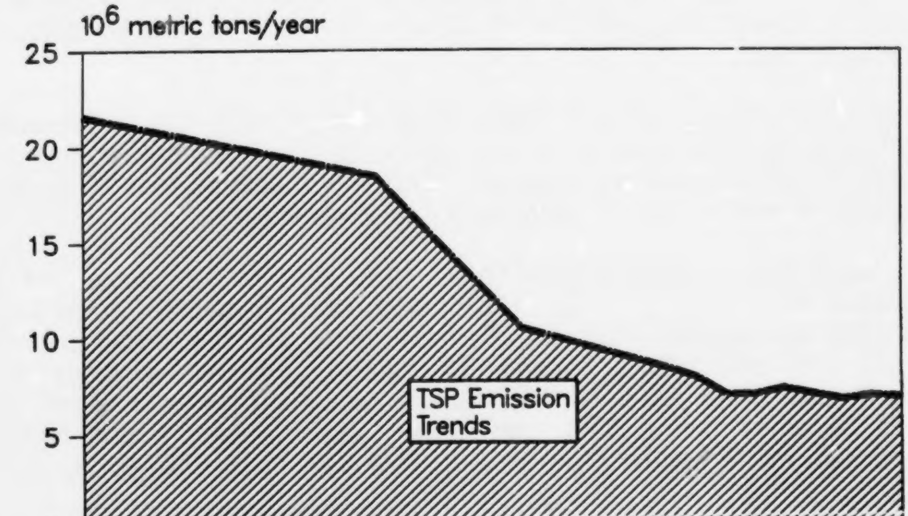

Figure 3-3. Historical trends in total particulate emissions, 1960-1988

While ambient TSP concentrations have declined approximately 50 percent, estimated emissions among inventoried sources have been cut by two thirds (Figure 3-3). Since these estimated emissions do not include many sources which contribute to natural background and also do not include unpaved roads and construction activity, the smaller improvement in ambient air quality is understandable.

3.1.2 Long-term TSP Trends: 1979-88

The 10-year trend in average TSP levels, 1979 through 1988, is shown in Figure 3-4 for 1750 sites geographically distributed throughout the Nation. Trends are also shown for the subset of 450 National Air Monitoring Stations (NAMS) which are located in areas of greater than 50,000 in population. The TSP levels are expressed in terms of the composite average annual geometric mean.

The curves in Figure 3-4 show identical trends for both the NAMS and the larger group of sites, although composite particulate concentrations are higher for the NAMS. For both curves, composite TSP concentrations declined during the early part of the 10-year period and are relatively stable in the later years. The data collected during 1979-1981 may have been affected by the type of filters used to collect the TSP.[2] For this reason, the portion of Figure 3-4 corresponding to the years 1979-1981 are stippled, to indicate the uncertainty in the TSP measurements collected during this period. Previous trends reports have determined that 1978 levels were produced with valid filters and that composite 1979 levels were only one percent higher. Therefore, the 10-year comparisons can be legitimately determined using 1979 as a base year. Although the difference between 1979 and post-1981 is real, the pattern of the yearly change in TSP between 1979 and 1981 is difficult to assess and most of the large apparent decrease in pollutant concentrations between 1981 and 1982 can be attributed to a change in these filters.[2-5]

The composite average of TSP levels measured at 1750 sites, distributed throughout the Nation, decreased 20 percent during the 1979 to 1988 time period, and the subset of 450 NAMS decreased 19 percent. Figure 3-4 also includes 95 percent confidence intervals developed for the composite annual estimates.

It can be seen that the estimates for 1982 - 1988 are relatively stable and are all significantly lower than those of 1979 - 1981. Upon close inspection, some slight changes since 1982 are evident. First, the minimum composite TSP levels occurred during the years 1985 and 1986. Second, statistically significant increases were detected during the last three years, so that 1988 concentration levels have returned to earlier levels observed during 1982 and 1984. These recent trends in total suspended particulate matter will be discussed in more detail in Section 3.1.3.

The long-term trends in TSP are also illustrated in Figure 3-5. Using the same national data base of 1750 TSP sites, Figure 3-5 shows the yearly change in the entire national concentration distribution using boxplot displays. A decrease occurred at every percentile level between 1979 and 1988, further indicating a broad national improvement in ambient particulate concentrations throughout the country.

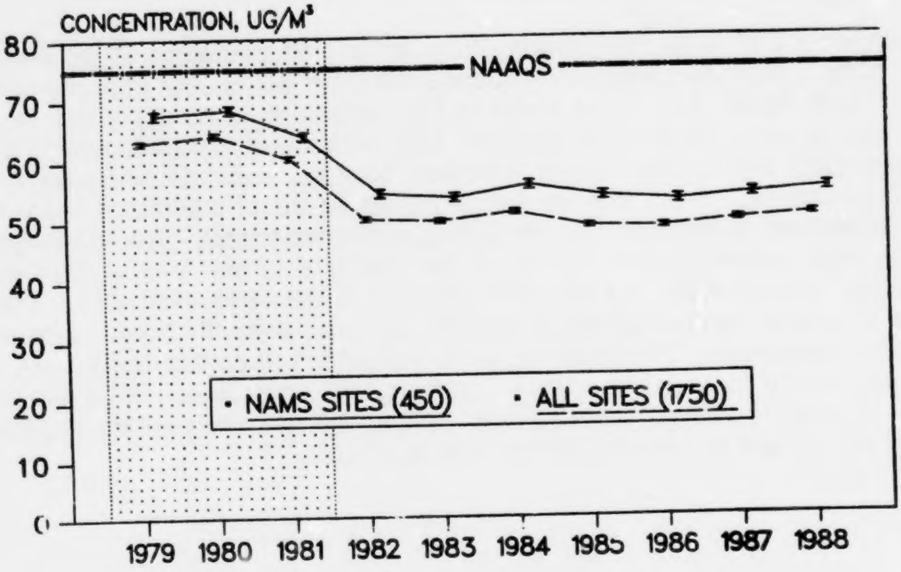

Figure 3-4. National trend in the composite average of the geometric mean total suspended particulate at both NAMS and all sites with 95 percent confidence intervals, 1979-1988.

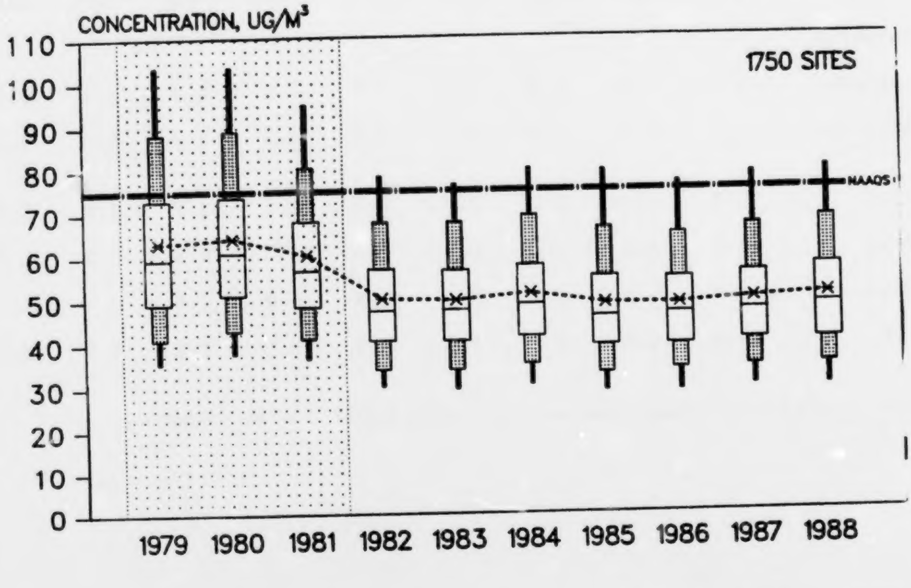

Figure 3-5. Boxplot comparisons of trends in annual geometric mean total suspended particulate concentrations at 1750 sites, 1979-1988.

Nationwide TSP emission trends show an overall decrease of 22 percent from 1979 to 1988 which coincidentally matches the TSP air quality improvement. (See Table 3-1 and Figure 3-6). The trend in PM emissions is normally not expected to agree precisely with the trend in ambient TSP levels due to unaccounted for natural PM background and uninventoried emission sources such as unpaved roads and construction activity. Such fugitive emissions could be of significant magnitude and are not considered in estimates of the annual nationwide total. Due to delays in 1988 emissions data reporting, the impact of the massive forest fires which occurred in Yellowstone National Park, are also not reflected in the 1988 estimates. The 10-year reduction in inventoried particulate emissions occurred primarily because of reductions in industrial processes. This is attributed to installation of control equipment, and also to reduced activity in some industries, such as iron and steel. Other areas of TSP emission reductions include reduced coal burning by non-utility users and installation of control equipment by electric utilities that burn coal.[1]

Table 3-1. National Total Suspended Particulate Emission Estimates, 1979-1988.

(million metric tons/year)

Source Category	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Transportation	1.4	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4
Fuel Combustion	2.5	2.4	2.3	2.2	2.0	2.1	1.8	1.8	1.8	1.7
Industrial Processes	3.8	3.3	3.0	2.6	2.4	2.8	2.8	2.5	2.5	2.6
Solid Waste	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Miscellaneous	0.9	1.1	0.9	0.7	1.1	0.9	0.8	0.8	1.0	0.9
Total	8.9	8.5	8.0	7.1	7.1	7.4	7.1	6.8	7.0	6.9

NOTE: The sums of sub-categories may not equal total due to rounding.

3.1.3 Recent TSP Trends: 1984-88

The TSP trends for the 5-year period 1984 through 1988 are presented in terms of 1491 sites which produced data in at least 4 of these 5 years. The group of sites qualifying for this analysis is smaller than the group used to analyze long-term trends, reflecting the revisions to TSP SLAMS networks and the shift of particulate monitoring to PM_{10}. Figure 3-7 presents a boxplot display of the 1984-1988 annual TSP concentration distributions. Very little change in TSP concentrations is evident between 1984 and 1988. A small 2 percent increase was seen between 1987 and 1988. This pattern in air quality, however, does not match the 5-year trend in national particulate emission estimates.

Particulate emissions are reported to have decreased 7 percent from 1984 to 1988. This 5-year decline in inventoried sources may be overstated, somewhat, because the major forest fires in Yellowstone during the summer of 1988 have not been included in the 1988 estimates. Emissions from forest fires typically represent 10 to 14 percent of the national total. The estimate reported for 1988 is only 11 percent. Figure 3-8 focuses on the last 3 years with a bar chart of Regional average TSP. Overall there were relatively small changes in most Regions. The largest decrease in total particulate concentrations is seen in Region X, which experienced an unusually high number of wildfires during 1987.[6]

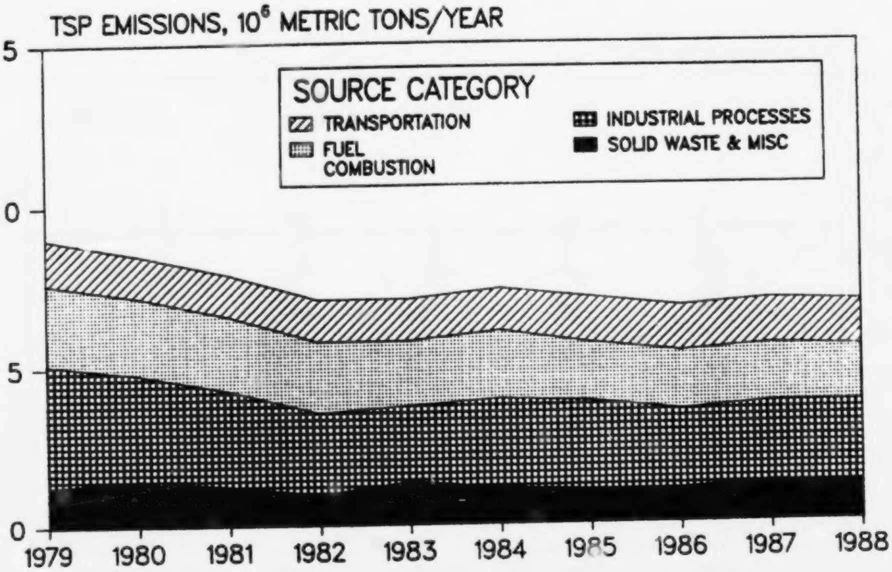

Figure 3-6. National trend in particulate emissions, 1979-1988.

3.1.4 Effect of Meteorology on Short-term Trends

The observed year-to-year variations in particulate levels may in part be attributable to meteorology. Among all meteorological parameters, precipitation has been shown to have had the greatest influence on particulate air quality. Rainfall has the effect of reducing reentrainment of particles and of washing particles out of the air. Generally drier conditions are also associated with an increase in forest fires.

During 1988, most of the nation experienced an extreme drought. Nationally, this year was the driest since 1956 and the second driest in the last 50 years. While the total precipitation decreased 13 percent from 1987, one fifth of the States experienced decreases exceeding 20 percent. The dry conditions were most severe in the southern Atlantic States (VA, NC, SC), the Midwest (IL, IA, MO, KS, NE) extending southward (OK, TX) and included the West (CA, NV, AZ) and the Mountain States (UT, WY, MT, ND).[7]

On a State-by-State basis, the largest decreases in precipitation were associated with the larger observed increases in TSP. Among those States with more than 20 percent decrease in precipitation (CA, IA, KS, NE, NV, OK, TX, UT, VA and WY), all except California, Texas and Wyoming increased in average TSP.

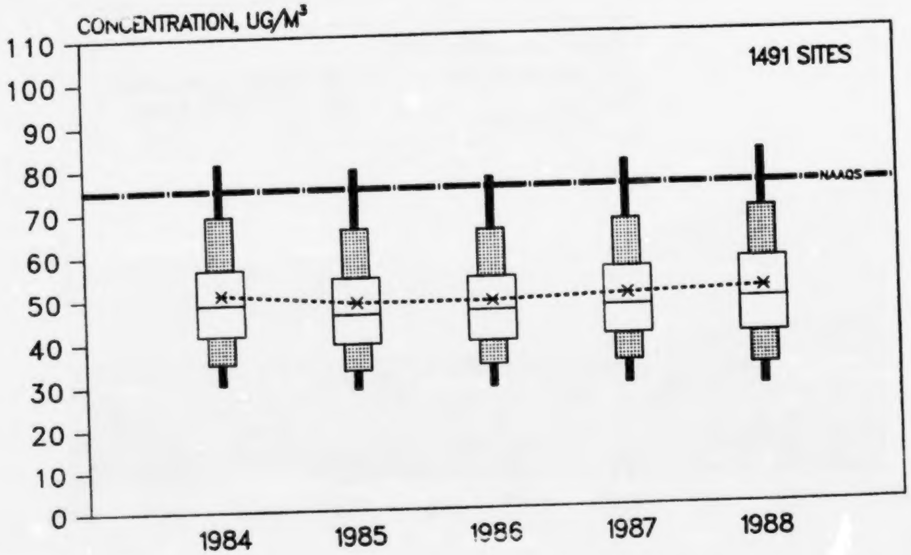

Figure 3-7. Boxplot comparisons of trends in annual mean total suspended particulate concentrations at 1491 sites, 1984-1988.

3.1.5 Recent PM_{10} Air Quality

The 1987-1988 change in the PM_{10} portion of total particulate concentrations is examined at a limited sample of 119 monitoring locations. This sample is not truly national, since it does not include any sampling stations in Region IX (CA, NV, AZ and HI) and only includes one site in Alaska to represent Region X. Nevertheless, it provides us with an indication of the year-to-year behavior of this new indicator for particulate matter. A more comprehensive national sample of 432 sites is also presented to provide a more representative indication of 1988 PM_{10} air quality produced by reference PM_{10} samplers.

The sample of 119 trend sites reveal a statistically significant 4 percent decrease in average PM_{10} concentrations. At the same sites, only an insignificant 1 percent decrease was noted in peak 24-hr concentrations. The 2-year decrease of 4 percent in average PM_{10} concentrations presents a somewhat different picture than the 2 percent increase described earlier for TSP. The contrast is even more notable for the 8 eastern most regions in which average TSP increased 3 percent.

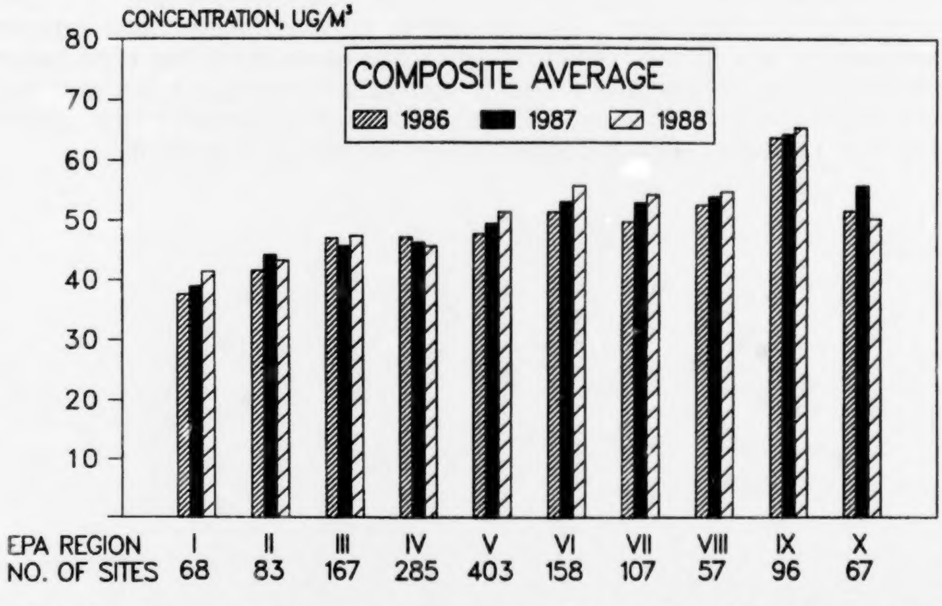

Figure 3-8. Regional comparisons of the 1986, 1987, 1988 composite averages of the geometric mean total suspended particulate concentration.

A subset of 63 sampling locations at which PM_{10} and TSP samplers were collocated during both years confirm that the PM_{10} portion of the total particulate, in fact, decreased from 59 percent in 1987 to 56 percent in 1988. Again it should be noted that the Western Regions are not well represented in this PM_{10} sample. The extremely dry conditions during 1988 may have had more impact on the larger particles (i.e. greater than 10 microns). However, the drought may have also affected PM_{10} concentrations, since the smallest changes in PM_{10} occurred in Regions VII and VIII whose States experienced the biggest drop in precipitation.

Figure 3-9 displays box-plots of the concentration distribution for the two PM_{10} trend statistics - annual arithmetic mean and 90th percentile of 24-hour concentrations - in order to place the 2-year change in air quality in the context of the more representative national sample of 432 sites. The 1988 PM_{10} at the 119 trend sites produced somewhat lower concentrations, both on average and for peak 24-hour concentrations. This is attributed to regional variations in PM_{10} concentrations, which are discussed later.

The more representative 1988 concentration distribution of annual arithmetic means also provides a basis for direct comparison to the annual standard of 50 $\mu g/m^3$. Approximately 8 percent of monitoring stations reported averages above the annual standard.

Although the 90th percentile is a reasonable indicator for temporal comparisons, it does not directly relate to the 150 $\mu g/m^3$ level of the 24-hour PM_{10} standard. Since this standard permits one expected exceedance per year, the maximum and second maximum 24-hour concentrations provide a more direct indication of attainment status. A comparison of the 90th percentile of 24-hour concentrations to these other indicators of peak concentrations is presented in Figure 3-10 using box-plots of the 1988 national concentration distribution. Although the 90th percentile concentrations are well below 150 $\mu g/m^3$, maximum concentrations exceed the standard at 13 percent of the reporting locations while the second maximum concentrations exceed at 6 percent.

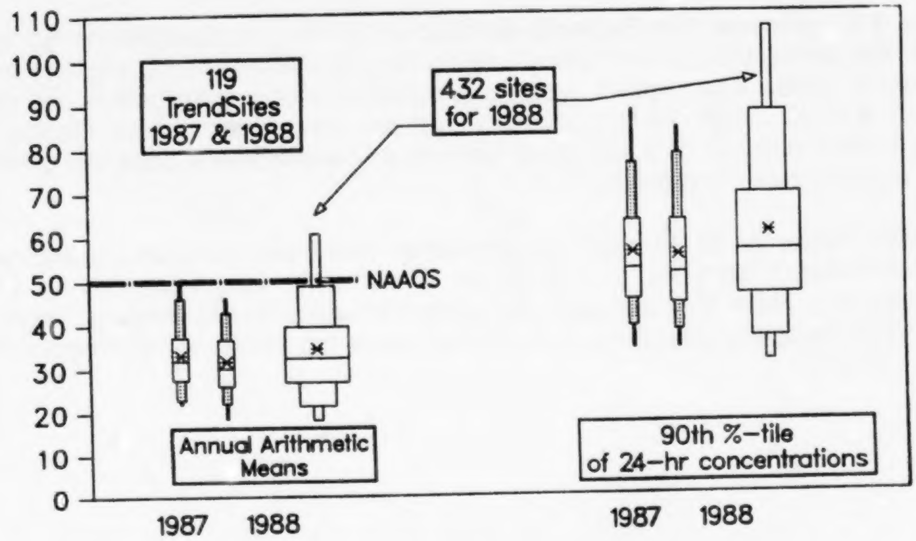

Figure 3-9. Boxplot comparisons of the 2-year change in PM_{10} concentrations (1987-1988) at 119 sites with 1988 PM_{10} air quality at 432 sites.

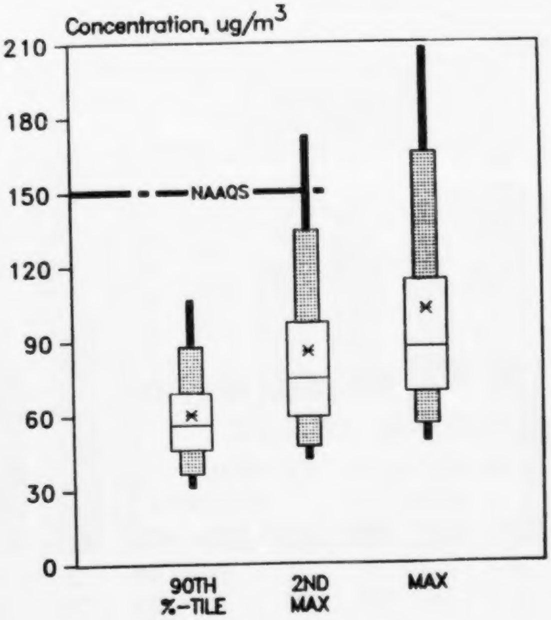

Figure 3-10. Boxplot comparisons of 24-hour PM_{10} peak value statistics for 1988 at 432 sites.

Figure 3-11 presents the Regional distribution of PM_{10} concentrations for both average and 90th percentile concentrations among the 432 stations producing reference measurements in 1988. The highest average and peak 24-hr concentrations are seen in Regions IX and X. High 24-hr concentrations are also observed for Region III, although the limited number of 5 sampling stations in Pennsylvania does not provide a regionally representative indicator.

The 90th percentile of 24-hour concentrations has been used as the indicator of peak concentrations because of differences in sampling frequency among PM_{10} sampling locations. Note that average sampling frequency varies among Regions, with Region VIII's samplers operating at more than twice the frequency of Region IX's.

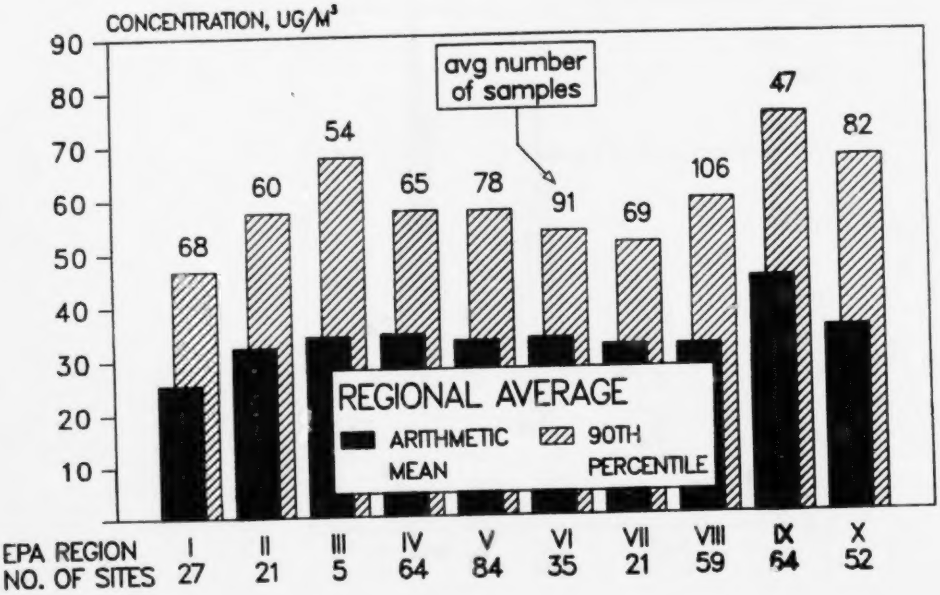

Figure 3-11. Regional comparisons of annual mean and 90th percentile of 24-hour PM_{10} concentrations.

3.2 TRENDS IN SULFUR DIOXIDE

Ambient sulfur dioxide (SO_2) results largely from stationary source coal and oil combustion, refineries, pulp and paper mills and from nonferrous smelters. There are three NAAQS for SO_2: an annual arithmetic mean of 0.03 ppm (80 $\mu g/m^3$), a 24-hour level of 0.14 ppm (365 $\mu g/m^3$) and a 3-hour level of 0.50 ppm (1300 $\mu g/m^3$). The first two standards are primary (health-related) standards, while the 3-hour NAAQS is a secondary (welfare-related) standard. The annual mean standard is not to be exceeded, while the short-term standards are not to be exceeded more than once per year. The trend analyses which follow are for the primary standards. It should be noted that EPA is currently evaluating the need for a new shorter-term 1-hour standard.[8]

Although this report does not directly address trends in acid deposition, of which SO_2 is a major contributor, it does include information on total nationwide emissions which is a measure relating to total atmospheric loadings.

The trends in ambient concentrations are derived from continuous monitoring instruments which can measure as many as 8760 hourly values per year. The SO_2 measurements reported in this section are summarized into a variety of summary statistics which relate to the SO_2 NAAQS. The statistics on which ambient trends will be reported are the annual arithmetic mean concentration, the second highest annual 24-hour average (summarized midnight to midnight), and the expected annual number of 24-hour exceedances of the 24-hour standard of 0.14 ppm.

3.2.1 Long-term SO_2 Trends: 1979-88

The long-term trend in ambient SO_2, 1979 through 1988, is graphically presented in Figures 3-12 through 3-14. In each figure, the trend at the NAMS is contrasted with the trend at all sites. For each of the statistics presented, a steady downward trend is evident through 1987, followed by a slight upturn in 1988. Nationally, the annual mean SO_2, examined at 374 sites, decreased at a median rate of approximately 4 percent per year; this resulted in an overall change of about 30 percent (Figure 3-12). The subset of 116 NAMS recorded higher average concentrations and also declined at the same median rate, with a net change of 33 percent for the 10-year period.

The annual second highest 24-hour values displayed a similar improvement between 1979 and 1988. Nationally, among 364 stations with adequate trend data, the median rate of change was 4 percent per year, with an overall decline of 36 percent (Figure 3-13). The 118 NAMS exhibited an overall decrease of 34 percent. The estimated number of exceedances also showed declines for the NAMS as well as for the composite of all sites (Figure 3-14). The national composite estimated number of exceedances decreased 90 percent from 1979 to 1988. However, the vast majority of SO_2 sites do not show any exceedances of the 24-hour NAAQS. Most of the exceedances as well as the bulk of the improvements occurred at source-oriented sites.

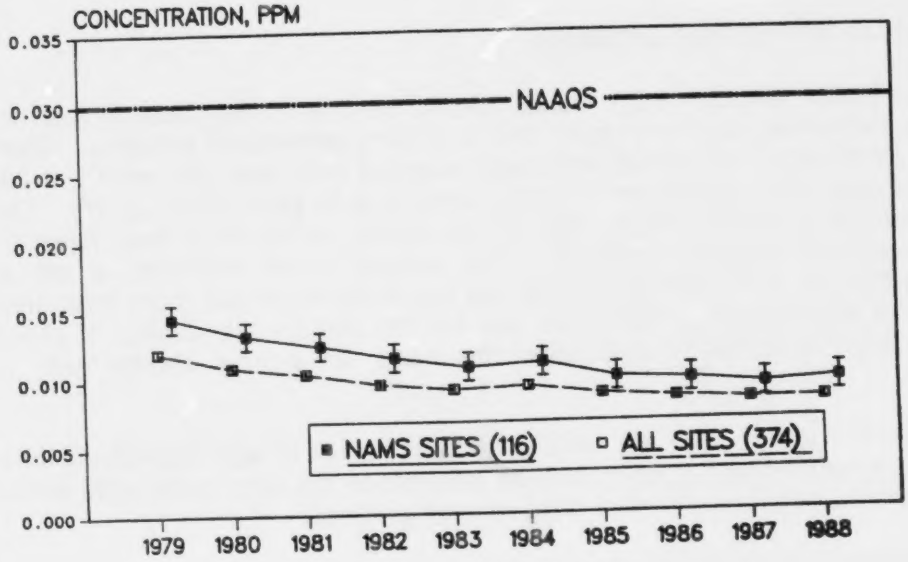

Figure 3-12. National trend in annual average sulfur dioxide concentration at both NAMS and all sites with 95 percent confidence intervals, 1979-1988.

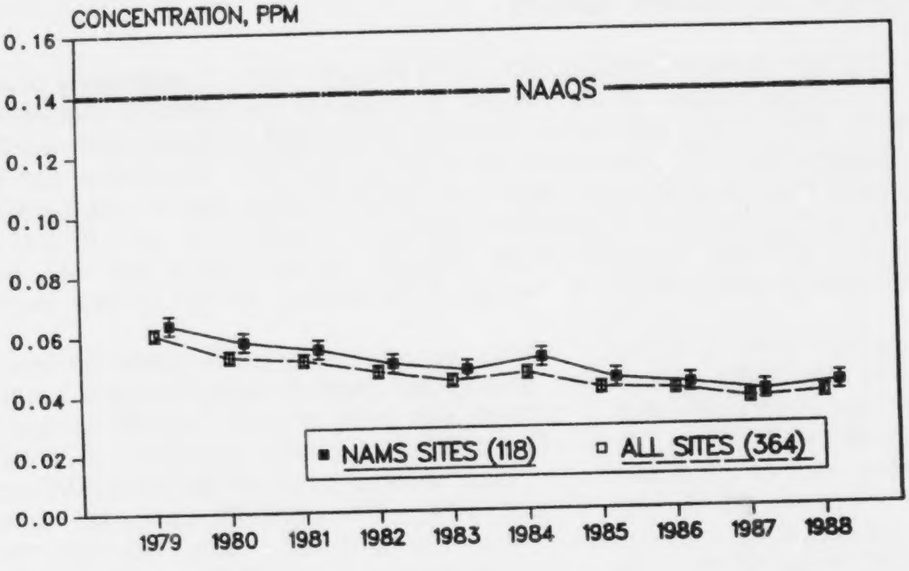

Figure 3-13. National trend in the second-highest 24-hour sulfur dioxide concentration at both NAMS and all sites with 95 percent confidence intervals, 1979-1988.

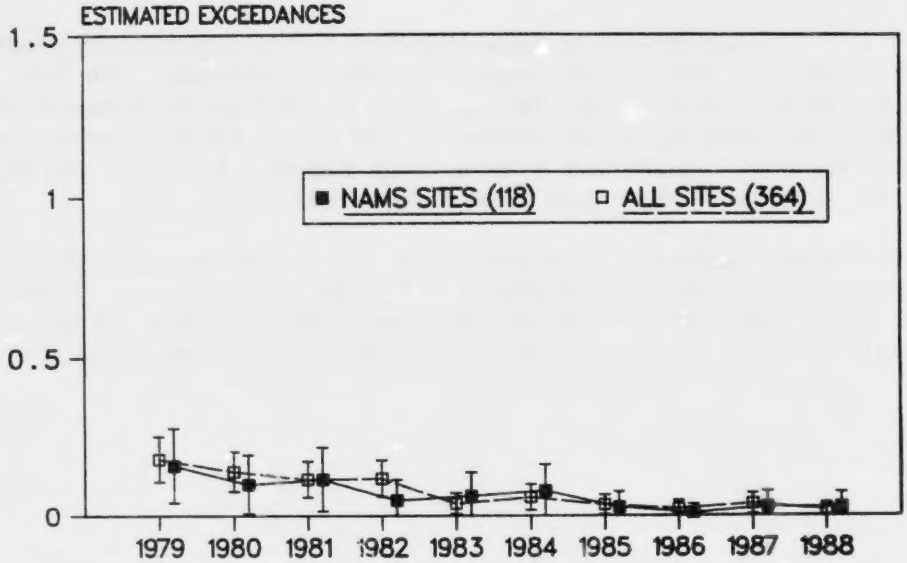

Figure 3-14. National trend in the estimated number of exceedances of the 24-hour sulfur dioxide NAAQS at both NAMS and all sites with 95 percent confidence intervals, 1979-1988.

The statistical significance of these long-term trends is graphically illustrated in Figures 3-12 to 3-14 with the 95 percent confidence intervals. For both annual averages and peak 24-hour values, the SO_2 levels in 1987 are the lowest in 10 years but are statistically indistinguishable among the last three. Expected exceedances of the 24-hour standard experienced a more rapid decline. For each statistic, 1988 averages are significantly lower than levels before 1983.

The inter-site variability for annual mean and annual second highest 24-hour SO_2 concentrations is graphically displayed in Figures 3-15 and 3-16. These figures show that higher concentrations decreased more rapidly and that the concentration range among sites has also diminished from the late 1970s to the present.

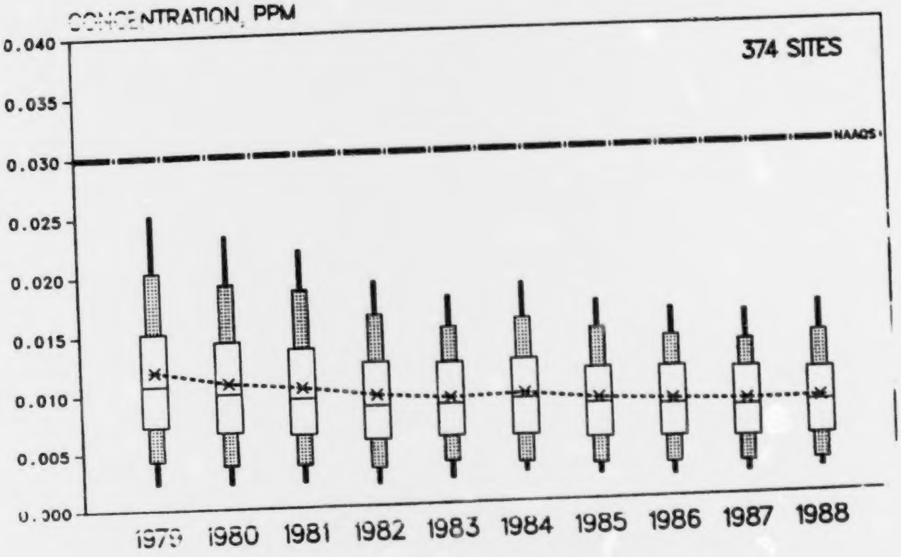

Figure 3-15. Boxplot comparisons of trends in annual mean sulfur dioxide concentrations at 374 sites, 1979-1988.

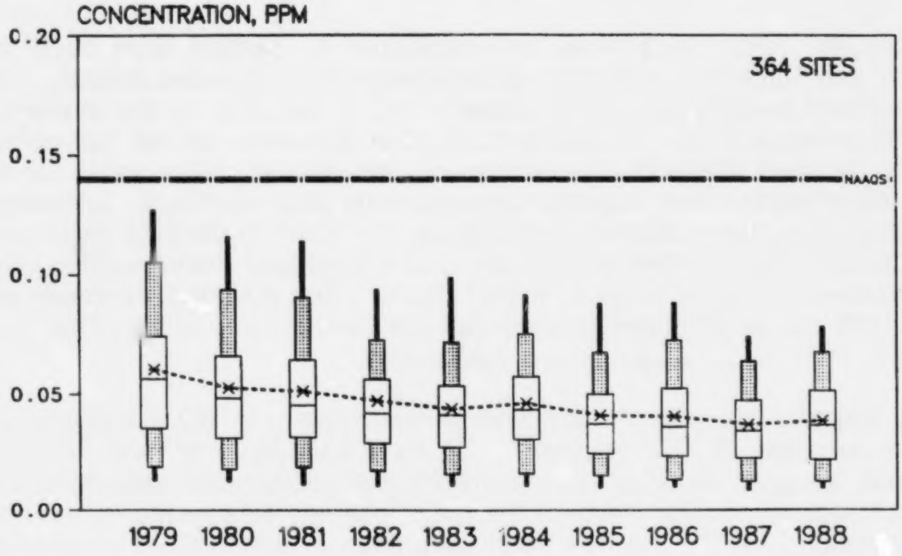

Figure 3-16. Boxplot comparisons of trends in second highest 24-hour average sulfur dioxide concentrations at 364 sites, 1979-1988.

Nationally, sulfur oxide emissions decreased 17 percent from 1979 to 1988 (Figure 3-17 and Table 3-2), reflecting the installation of flue gas desulfurization controls at new coal-fired electric generating stations and a reduction in the average sulfur content of fuels consumed. Emissions from other stationary source fuel combustion sectors also declined, mainly due to decreased combustion of coal by these consumers. Sulfur oxides emissions from industrial processes are also significant. Emissions from industrial processes have declined, primarily as the result of controls implemented to reduce emissions from nonferrous smelters and sulfuric acid manufacturing plants, as well as shutdowns of some large smelters.[1] Sulfur oxide emission increases between 1987 and 1988 can be attributed to increased industrial activity, which offset continued reductions in emissions caused by fuel combustion.

The disparity between the 30 percent improvement in SO_2 air quality and the 17 percent decrease in SO_x emissions can be attributed to several factors. SO_2 monitors with sufficient historical data for trends are mostly urban population-oriented, and as such, do not monitor many of the major emitters which tend to be located in more rural areas. Among the 374 trend sites used in the analysis of average SO_2 levels, approximately two-thirds are categorized as population-oriented. The remaining sites include those monitors in the vicinity of large power plants, nonferrous smelters and other industrial sources such as paper mills and steel producing facilities.

The residential and commercial areas, where most monitors are located, have shown sulfur oxides emission decreases comparable to SO_2 air quality improvement. These decreases in sulfur oxides emissions are due to a combination of energy conservation measures and the use of cleaner fuels in the residential and commercial areas.[1] Comparable SO_2 trends have also been demonstrated for monitors located in the vicinity of nonferrous smelters which produce some of the highest SO_2 concentrations observed nationally.[9] Smelter sources represent a majority of SO_x emissions in the intermountain region of the western U.S. Although one-third of the trend sites are categorized as source-oriented, the majority of SO_x emissions are dominated by large point sources. Two-thirds of all national SO_x emissions are generated by electric utilities (93 percent of which come from coal fired power plants). The majority of these emissions, however, are produced by a small number of facilities. Fifty individual plants in 15 states account for one-half of all power plant emissions. In addition, the 200 highest SO_x emitters account for more than 85 percent of all SO_x power plant emissions. These 200 plants account for 59 percent of all SO_x emissions nationally.[10]

Another factor which may account for differences in SO_x emissions and ambient air quality is stack height. At large utilities and smelters, SO_2 is generally released into the atmosphere through tall stacks. Under these circumstances, measured ground level concentrations in the vicinity of these sources may not reflect local emissions. Total atmospheric loading impacts also arise, in part, as a consequence of tall stacks.

Table 3-2. National Sulfur Oxides Emission Estimates, 1979-1988.

(million metric tons/year)

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Source Category										
Transportation	0.9	0.9	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9
Fuel Combustion	19.5	18.7	17.8	17.3	16.7	17.4	17.0	16.9	16.6	16.4
Industrial Processes	4.4	3.8	3.9	3.3	3.3	3.3	3.2	3.1	3.2	3.4
Solid Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Miscellaneous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	24.8	23.4	22.6	21.4	20.7	21.5	21.1	20.9	20.6	20.7

NOTE: The sums of sub-categories may not equal total due to rounding.

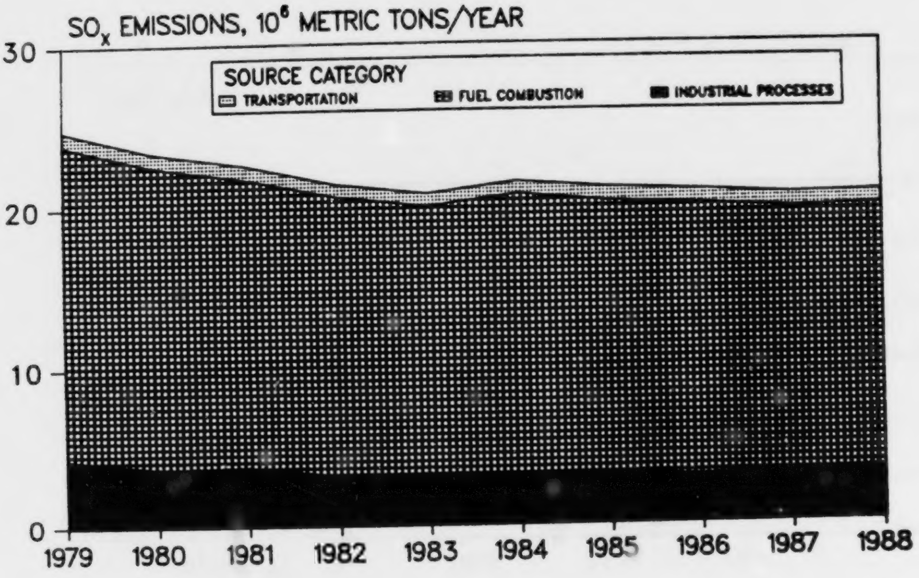

Figure 3-17. National trend in sulfur oxides emissions, 1979-1988.

3.2.2 Recent SO_2 Trends: 1984-88

Figure 3-18 presents boxplots for the 1984-1988 data using 584 SO_2 sites. The 5-year trend shows an 13 percent decline in average concentrations, indicating that the long term trend has continued but has been leveling off. Correspondingly, SO_x emissions have decreased only 4 percent over the last 5 years. Between 1987 and 1988, average ambient concentrations have increased 1 percent, corresponding to a less than 1 percent increase in total emissions.

Regional changes in composite average SO_2 concentrations for the last 3 years, 1986-1988, are shown in Figure 3-19. Several Regions show moderate increases between 1987 and 1988. Only Region X shows a consistent decline, resulting from lower monitored concentrations in the vicinity of State of Washington pulp mills.

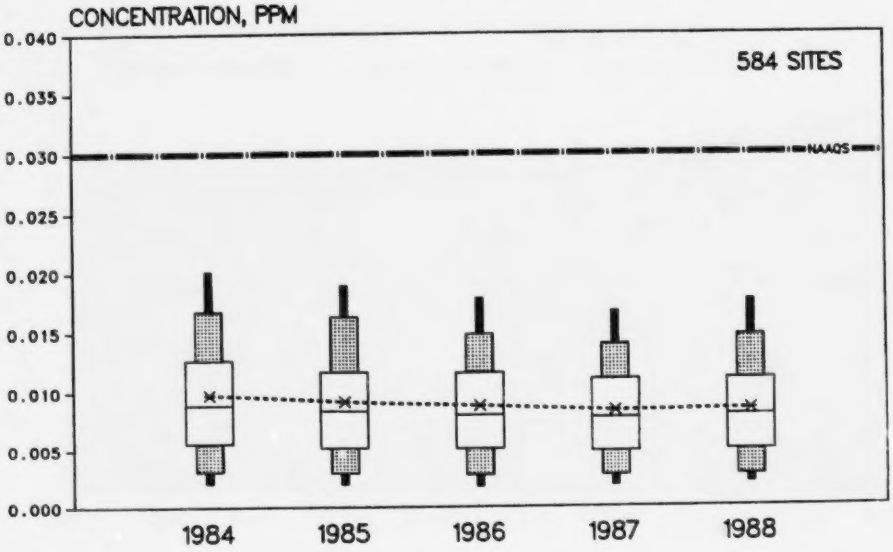

Figure 3-18. Boxplot comparisons of trends in annual mean sulfur dioxide concentrations at 584 sites, 1984-1988.

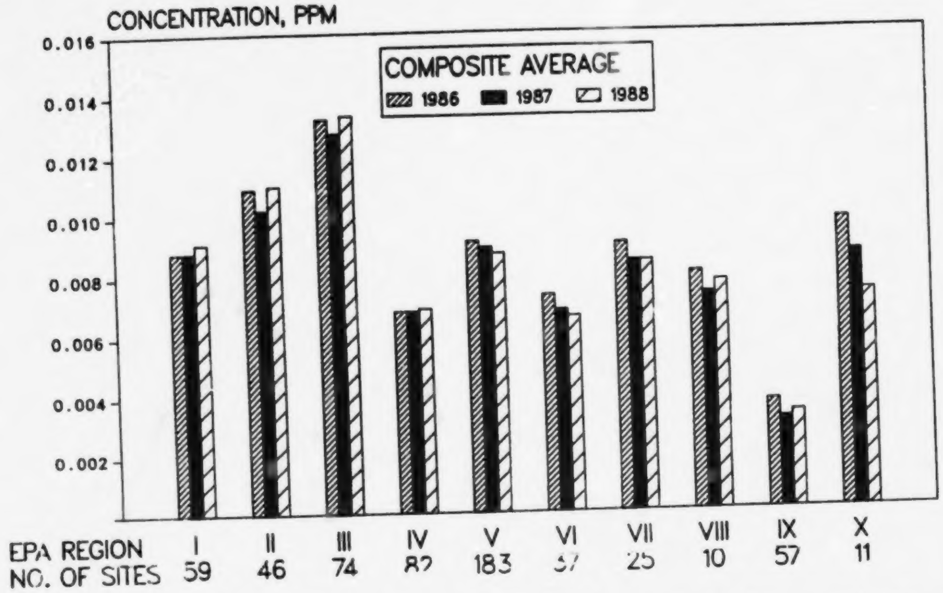

Figure 3-19. Regional comparisons of the 1986, 1987, 1988 composite averages of the annual average sulfur dioxide concentration.

3.3 TRENDS IN CARBON MONOXIDE

Carbon monoxide (CO) is a colorless, odorless, and poisonous gas produced by incomplete burning of carbon in fuels. Two-thirds of the nationwide CO emissions are from transportation sources, with the largest contribution coming from highway motor vehicles. The NAAQS for ambient CO specify upper limits for both 1-hour and 8-hour averages that are not to be exceeded more than once per year. The 1-hour level is 35 ppm, and the 8-hour level is 9 ppm. This trends analysis focuses on the 8-hour average results because the 8-hour standard is generally the more restrictive limit. In fact, only six exceedances of the CO 1-hour NAAQS were recorded for the nation during 1988.

Trends sites were selected using the procedures presented in Section 2.1 which yielded a data base of 248 sites for the 10-year period 1979-88 and a data base of 359 sites for the 5-year 1984-88 period. There were 72 NAMS sites included in the 10-year data base and 100 NAMS sites in the 5-year data base. This 45 percent increase in the number of trend sites available for the more recent time period is consistent with the improvement in size and stability of current ambient CO monitoring programs.

3.3.1 Long-term CO Trends: 1979-88

The 1979-88 composite national average trend is shown in Figure 3-20 for the second highest non-overlapping 8-hour CO value for the 248 long-term trend sites and the subset of 72 NAMS sites. During this 10-year period, both the national composite average and the subset of NAMS decreased by 28 percent. The median rate of improvement for this time period is slightly less than 4 percent per year. After leveling off to no significant change from 1985 to 1986, the trend resumed downward in 1987 and 1988. Long-term improvement was seen in each EPA Region with median rates of improvement varying from 2 to 5 percent per year. This same trend is shown in Figure 3-21 by a boxplot presentation which provides more information on the year-to-year distribution of ambient CO levels at the 248 long-term trend sites. While there is some year to year fluctuation in certain percentiles, the general long-term improvement in ambient CO levels is clear.

Figure 3-22 displays the 10-year trend in the composite average of the estimated number of exceedances of the 8-hour CO NAAQS. This exceedance rate was adjusted to account for incomplete sampling. The trend in exceedances shows long-term improvement but the rates are much higher than those for the second maximums. The composite average of estimated exceedances decreased 88 percent between 1979 and 1988 for the 248 long-term trend sites, while the subset of 72 NAMS showed an 82 percent decrease. These percentage changes for exceedances are typically much larger than those found for peak concentrations, such as the annual second maximum 8-hour value, which is more likely to reflect the change in emission levels.

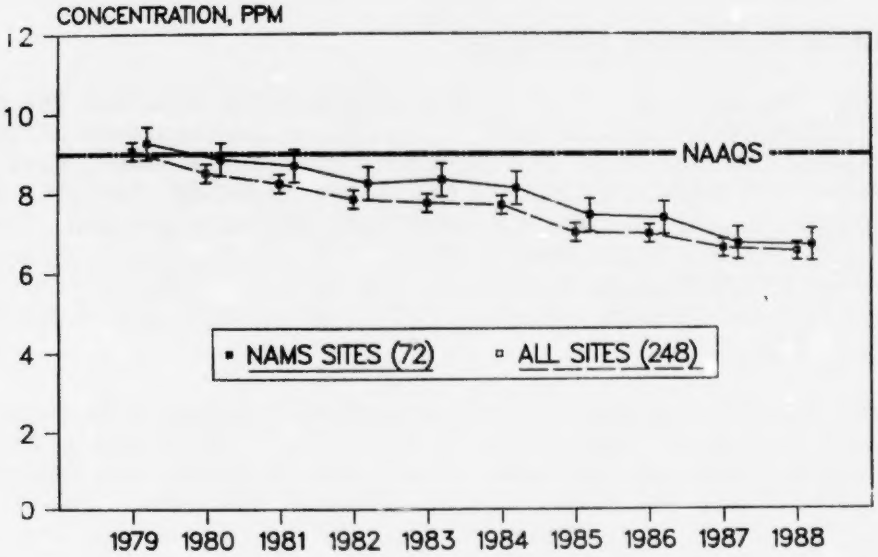

Figure 3-20. National trend in the composite average of the second highest nonoverlapping 8-hour average carbon monoxide concentration at both NAMS and all sites with 95 percent confidence intervals, 1979-1988.

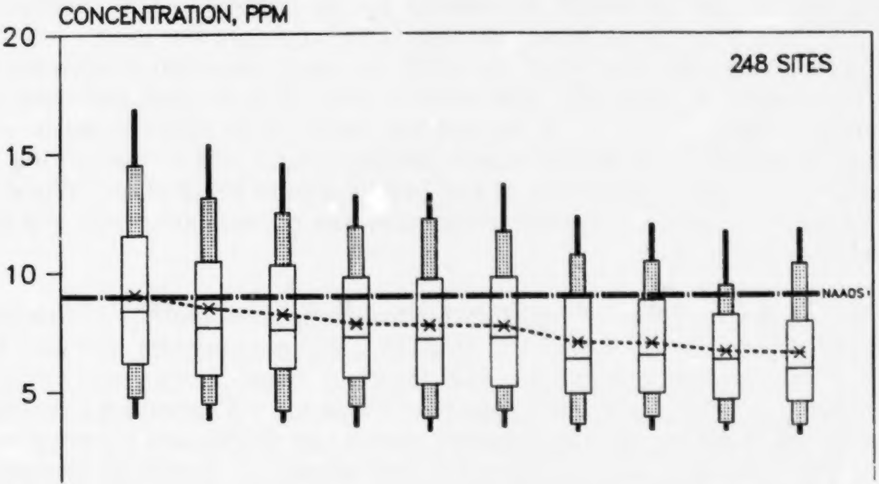

Figure 3-21. Boxplot comparisons of trends in second highest nonoverlapping 8-hour average carbon monoxide concentrations at 248 sites, 1979-1988.

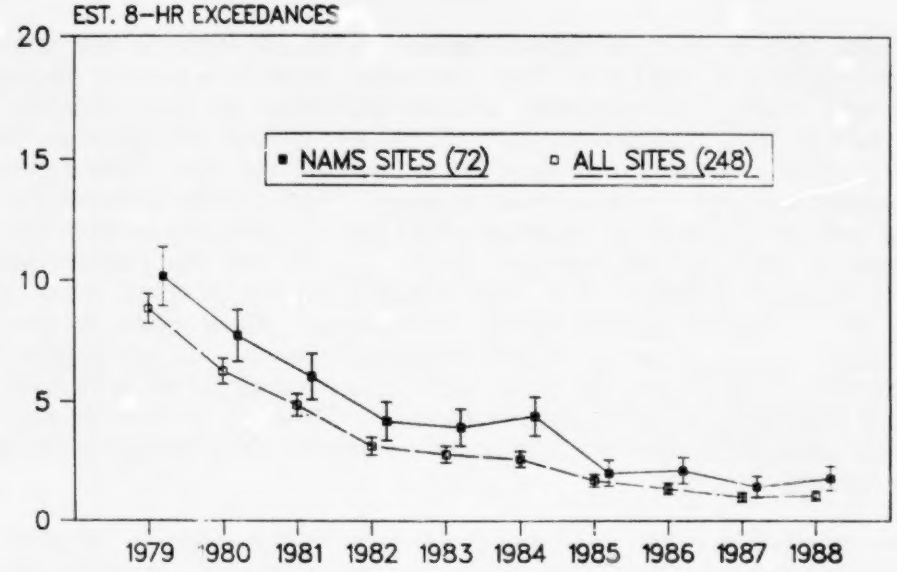

Figure 3-22. National trend in the composite average of the estimated number of exceedances of the 8-hour carbon monoxide NAAQS, at both NAMS and all sites with 95 percent confidence intervals, 1979-88.

The 10-year 1979-88 trend in national carbon monoxide emission estimates is shown in Figure 3-23 and in Table 3-3. These estimates show a 25 percent decrease between 1979 and 1988. Transportation sources accounted for approximately 72 percent of the total in 1979 and decreased to 67 percent of total emissions in 1988. Emissions from highway vehicles decreased 30 percent during the 1979-88 period, despite a 33 percent increase in vehicle miles of travel.[1] Figure 3-24 contrasts the 10 year increasing trend in vehicle miles travelled (VMT) with the declining trend in carbon monoxide emissions from highway vehicles. This indicates that the Federal Motor Vehicle Control Program (FMVCP) has been effective on the national scale, with controls more than offsetting growth during this period. While there is general agreement between changes in air quality and emissions over this 10-year period, it is worth noting that the emission changes reflect estimated national totals, while ambient CO monitors are frequently located to identify problems. The mix of vehicles and the change in vehicle miles of travel in the area around a specific CO monitoring site may differ from the national averages.

Despite the progress that has been made, CO remains a concern in many urban areas. The characterization of the CO problem is complicated because of the growth and possible changes in traffic patterns that have occurred in many major urban areas. There are a variety of possible factors to consider, such as topography, meteorology, and localized traffic flow. The goal is to ensure that the monitoring networks continue to characterize the ambient CO problem adequately. However, these concerns should not overshadow the genuine progress documented over time in areas that have traditionally been the focus of the CO problem.

3.3.2 Recent CO Trends: 1984-88

This section examines ambient CO trends for the 5-year period 1984-88. As discussed in section 2.1, this allows the use of a larger data base, 359 sites versus 248. Figure 3-25 displays the 5-year ambient CO trend in terms of the second highest non-overlapping 8-hour averages. These sites showed a 16 percent decrease between 1984 and 1988. The general patterns are consistent with the longer term data base and, after no change between 1985 and 1986, levels resumed their decline. The 1988 composite average is 3 percent lower than the 1987 composite average. Table 3-3 indicates that estimated total CO emissions decreased 15 percent during this 5-year period and that emissions from transportation sources decreased 19 percent.

Table 3-3. National Carbon Monoxide Emission Estimates, 1979-1988.

(million metric tons/year)

Source Category	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Transportation	59.1	56.1	55.4	52.9	52.4	50.6	47.9	44.6	43.2	41.2
Fuel Combustion	6.7	7.4	7.7	8.2	8.2	8.3	7.4	7.5	7.6	7.6
Industrial Processes	7.1	6.3	5.9	4.3	4.3	4.7	4.4	4.3	4.5	4.7
Solid Waste	2.3	2.2	2.1	2.0	1.9	1.9	2.0	1.7	1.7	1.7
Miscellaneous	6.5	7.6	6.4	4.9	7.7	6.3	5.3	5.0	7.1	6.0
Total	81.7	79.6	77.4	72.4	74.5	71.8	67.0	63.1	64.1	61.2

NOTE: The sums of sub-categories may not equal total due to rounding.

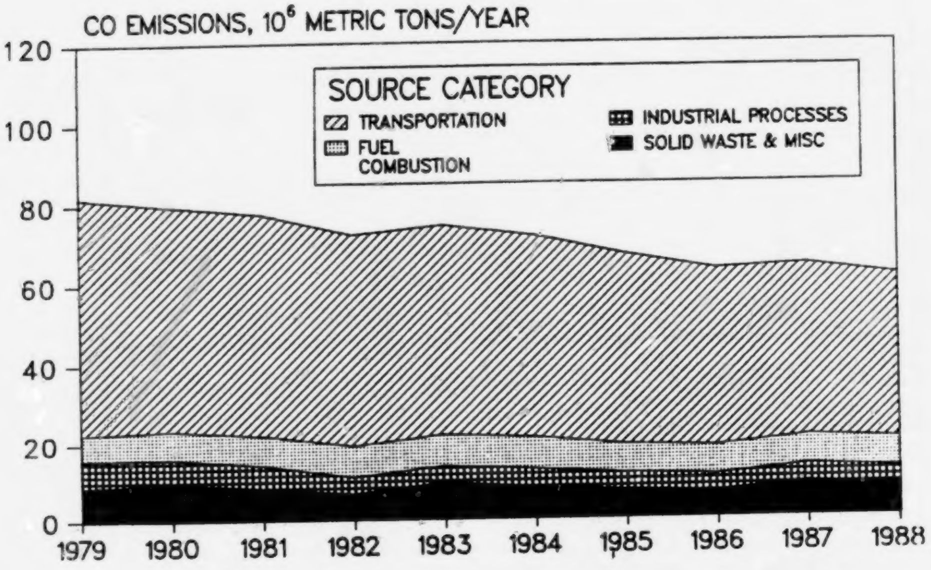

Figure 3-23. National trend in emissions of carbon monoxide, 1979-1988.

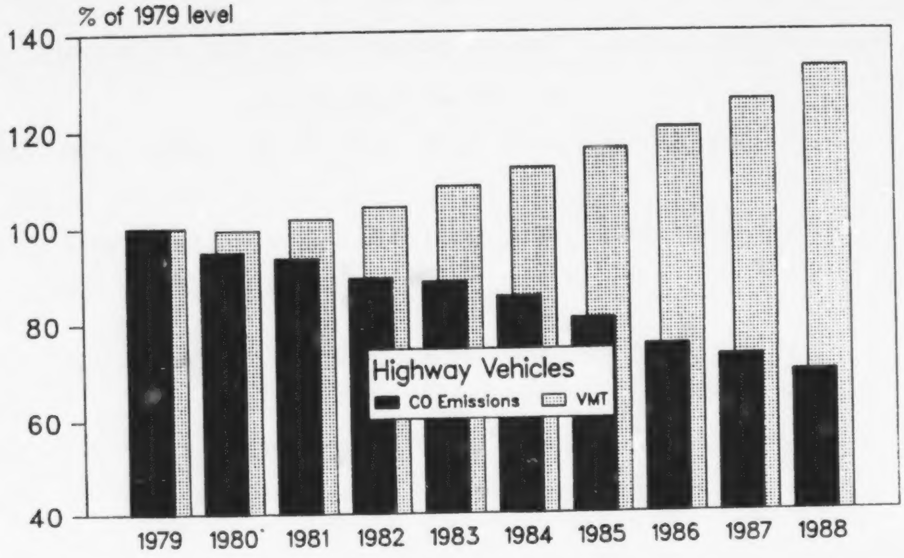

Figure 3-24. Comparison of trends in total National vehicle miles traveled and National highway vehicle emissions, 1979-1988.

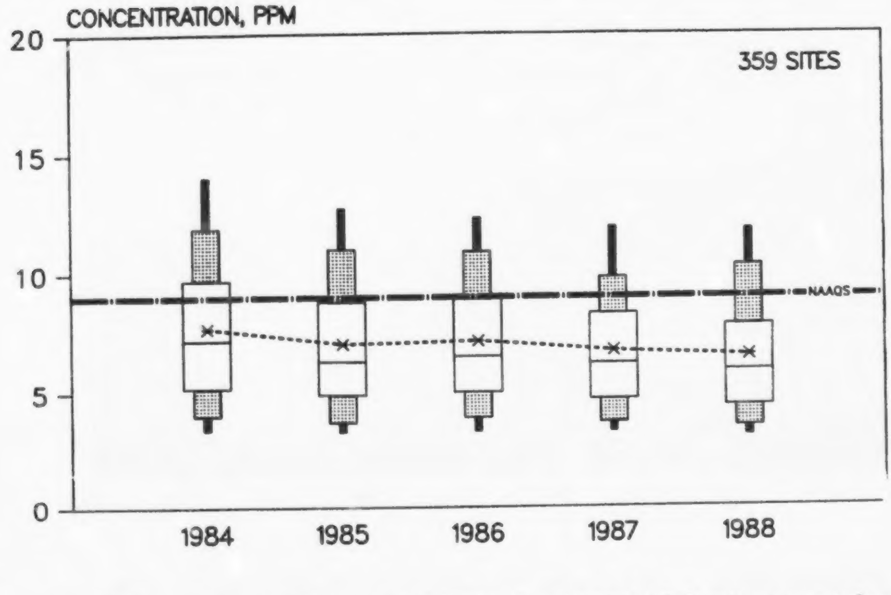

Figure 3-25. Boxplot comparisons of trends in second highest nonoverlapping 8-hour average carbon monoxide concentrations at 359 sites, 1984-1988.

Figure 3-26 shows the composite Regional averages for the 1984-88 time period. Eight of the ten Regions have 1988 composite levels lower than 1987 levels. The composite average in Region IX increased 9 percent, while Region IV showed no change. These Regional graphs are primarily intended to depict relative change. Because the mix of monitoring sites may vary from one area to another, this graph is not intended to indicate Regional differences in absolute concentration levels.

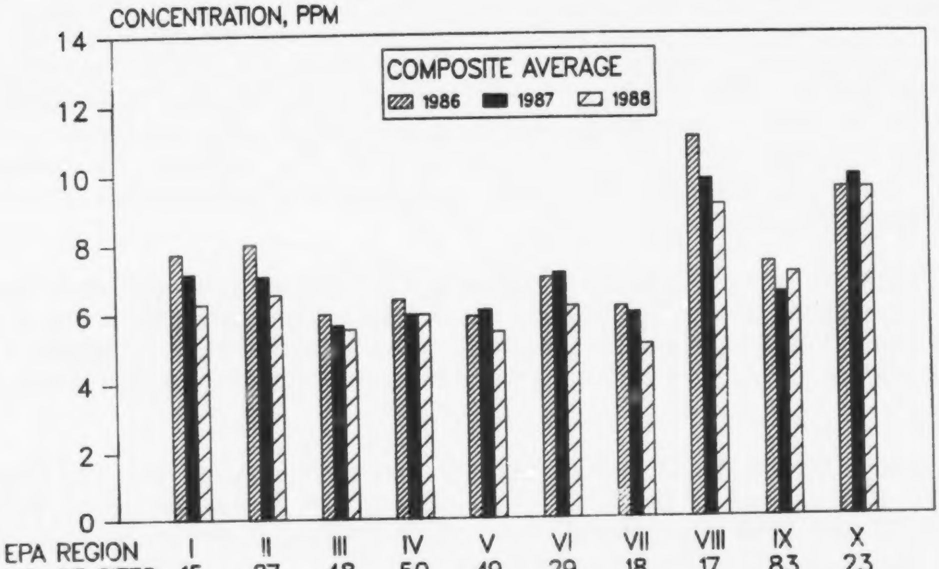

Figure 3-26. Regional comparisons of the 1986, 1987, 1988 composite averages of the second highest non-overlapping 8-hour average carbon monoxide concentration.

3.4 TRENDS IN NITROGEN DIOXIDE

Nitrogen dioxide (NO_2) is a yellowish brown, highly reactive gas which is present in urban atmospheres. The major mechanism for the formation of NO_2 in the atmosphere is the oxidation of the primary air pollutant, nitric oxide (NO). It plays a major role, together with volatile organic compounds, in the atmospheric reactions that produce ozone. Nitrogen oxides form when fuel is burned at high temperatures. The two major emissions sources are transportation and stationary fuel combustion sources such as electric utility and industrial boilers.

Nitrogen oxides can irritate the lungs, cause bronchitis and pneumonia, and lower resistance to respiratory infections. Los Angeles, CA is the only urban area that has recorded violations of the annual NO_2 standard of 0.053 ppm during the past 10 years.

NO_2 is measured using a continuous monitoring instrument which can collect as many as 8760 hourly observations per year. Only annual means based on at least 4380 hourly observations were considered in the trends analyses which follow. A total of 116 sites were selected for the 10-year period and 194 sites were selected for the 5-year data base.

3.4.1 Long-term NO_2 Trends: 1979-88

The composite average long-term trend for the nitrogen dioxide mean concentrations at the 116 trend sites and the 27 NAMS sites, is shown in Figure 3-27. Nationally, composite annual average NO_2 levels decreased from 1979 to 1983, and have remained essentially constant since 1984. The 1988 composite average NO_2 level is 7 percent lower than the 1979 level, indicating an overall downward trend during this period. A similar trend is seen for the NAMS sites which, for NO_2, are located only in urban areas with populations of 1,000,000 or greater. As expected, the composite averages of the NAMS are higher than those of all sites, and they recorded a 6 percent decrease during this period.

In Figure 3-27, the 95 percent confidence intervals about the composite means allow for comparisons among the years. There are no significant differences among the recent years, for all sites and for the NAMS. The 1987 and 1988 composite mean NO_2 levels are not significantly different from one another, but 1988 is significantly less than 1979.

Long-term trends in NO_2 annual average concentrations are also displayed in Figure 3-28 with the use of boxplots. The improvement in the composite average between 1979 and 1988 can generally be seen in the upper percentiles until 1984. The lower percentiles show little change, however.

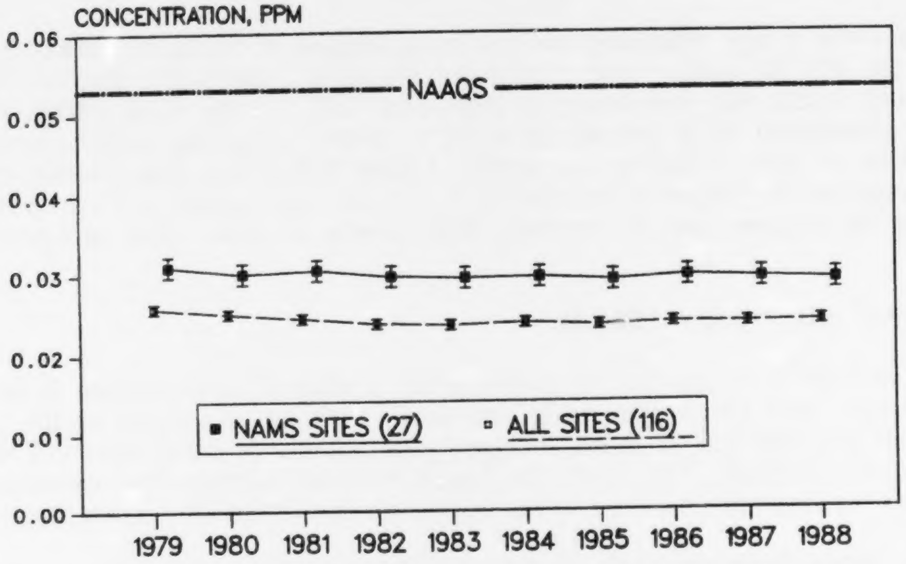

Figure 3-27. National trend in the composite average of nitrogen dioxide concentration at both NAMS and all sites with 95 percent confidence intervals, 1979-1988.

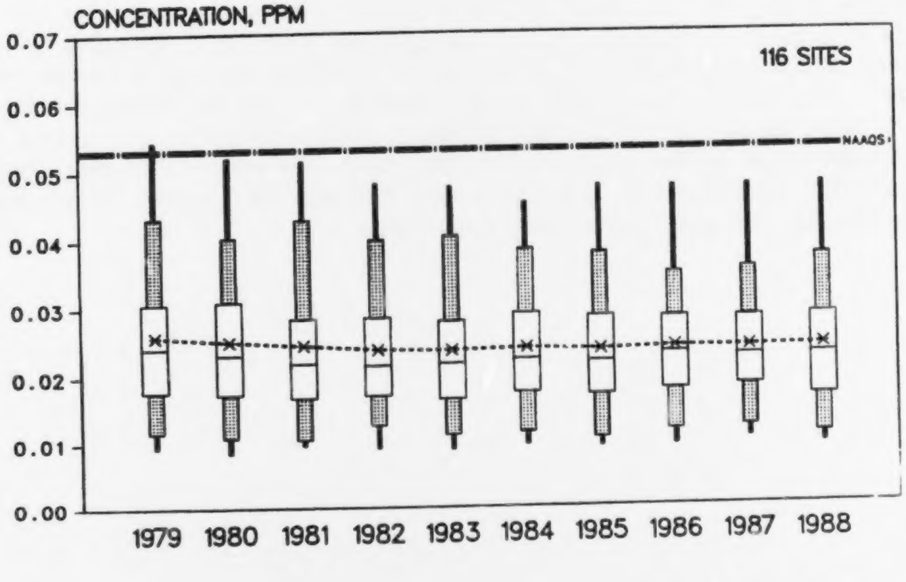

Figure 3-28. Boxplot comparisons of trends in annual mean nitrogen dioxide concentrations at 116 sites, 1979-1988.

The trend in the estimated nationwide emissions of nitrogen oxides (NO_x) is similar to the NO_2 air quality trend. Table 3-4 shows NO_x emissions decreasing from 1979 through 1983 then increasing in 1984 and 1985. Total 1988 nitrogen oxide emissions decreased by 8 percent from 1979 levels. Highway vehicle emissions decreased by 24 percent during this period. Figure 3-29 shows that the two primary source categories of nitrogen oxide emissions are fuel combustion and transportation, composing 55 percent and 41 percent, respectively, of total 1988 nitrogen oxide emissions.

3.4.2 Recent NO_2 Trends: 1984-88

Figure 3-30 uses the boxplot presentation to display recent trends in nitrogen dioxide annual mean concentrations for the years 1984-88. Focusing on the past 5 years, rather than the last 10 years, increases the number of sites, from 116 to 194, available for the analysis. The composite means from the recent period are essentially the same as the long-term means and the trends are consistent for the two data bases.

The composite average NO_2 level for the 194 trend sites has remained relatively constant during the last 5 years. The 1988 composite mean is less than 1 percent higher than the composite mean for 1984. The 1988 composite mean concentration is 1 percent higher than the 1987 level. During this same period, 1988 total nationwide emissions of nitrogen oxides returned to 1984 levels after declining in 1986. Between 1987 and 1988, total emissions of nitrogen oxides increased 3 percent, primarily due to fuel combustion emissions resulting from increased industrial activity.

Regional trends in the composite average NO_2 concentrations for the years 1986-88 are displayed in Figure 3-31 with bar graphs. Region X, which did not have any NO_2 sites which met the 5-year trends data completeness and continuity criteria, is not shown. The pattern of the year-to-year changes is mixed among the Regions. Although the national composite average showed no change during this period, seven Regions showed small increases from 1986 to 1987. Between 1987 and 1988, five Regions recorded decreases in the composite average NO_2 levels, three Regions recorded increases and one Region was unchanged.

Table 3-4. National Nitrogen Oxides Emission Estimates, 1979-1988.

(million metric tons/year)

Source Category	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Transportation	10.1	9.8	10.0	9.4	8.9	8.8	8.9	8.3	8.0	8.1
Fuel Combustion	10.5	10.1	10.0	9.8	9.6	10.2	10.2	10.0	10.5	10.8
Industrial Processes	0.7	0.7	0.6	0.5	0.5	0.6	0.6	0.6	0.6	0.6
Solid Waste	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Miscellaneous	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.2
Total	21.6	20.9	20.9	20.0	19.3	19.8	19.8	19.0	19.3	19.8

NOTE: The sums of sub-categories may not equal total due to rounding.

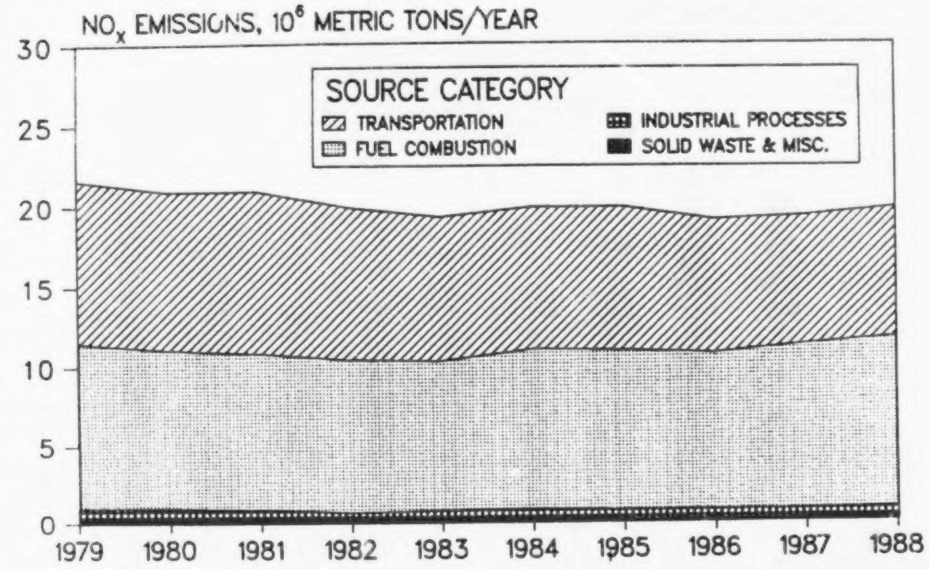

Figure 3-29. National trend in nitrogen oxides emissions, 1979-1988.

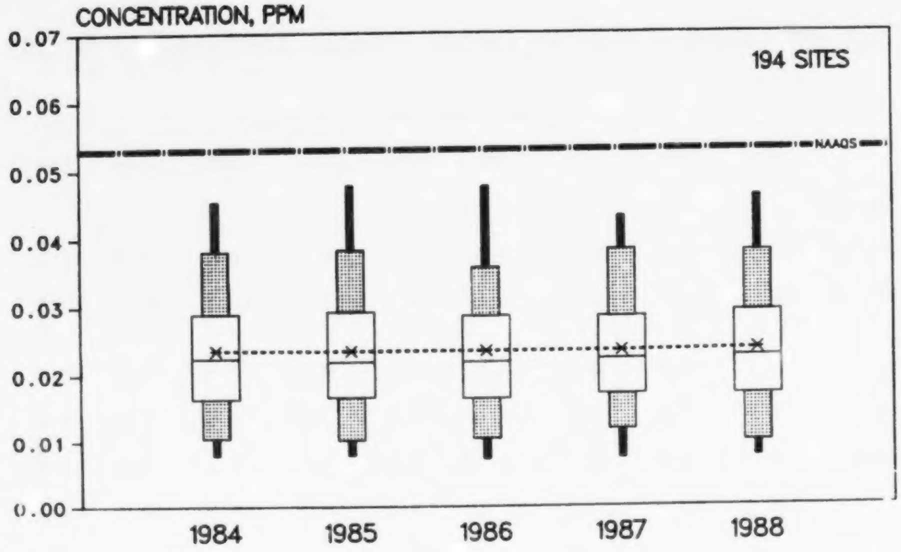

Figure 3-30. Boxplot comparisons of trends in annual mean nitrogen dioxide concentrations at 194 sites, 1984-1988.

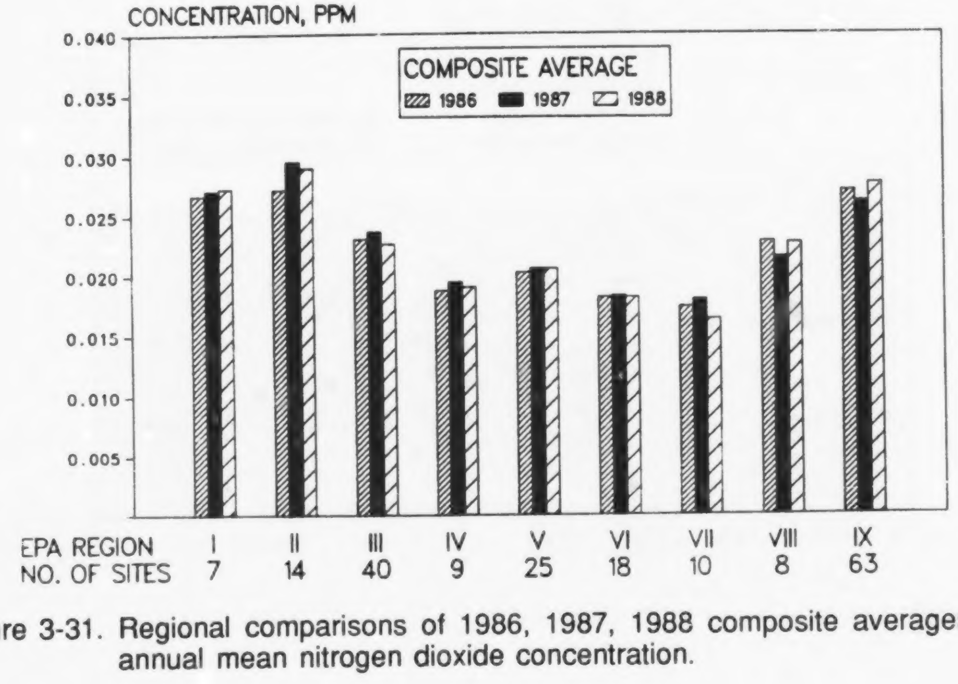

Figure 3-31. Regional comparisons of 1986, 1987, 1988 composite averages of the annual mean nitrogen dioxide concentration.

3.5 TRENDS IN OZONE

Ozone (O_3) is a photochemical oxidant and the major component of smog. While ozone in the upper atmosphere is beneficial to life by shielding the earth from harmful ultraviolet radiation given off by the sun, high concentrations of ozone at ground level are a major health and environmental concern. Ozone is not emitted directly into the air but is formed through complex chemical reactions between precursor emissions of volatile organic compounds and nitrogen oxides in the presence of sunlight. These reactions are stimulated by sunlight and temperature so that peak ozone levels occur typically during the warmer times of the year. Both volatile organic compounds and nitrogen oxides are emitted by transportation and industrial sources. Volatile organic compounds are emitted from sources as diverse as autos, chemical manufacturing, and dry cleaners, paint shops and other sources using solvents. The strong seasonality of ozone levels makes it possible for areas to limit their ozone monitoring to a certain portion of the year, termed the ozone season. The length of the ozone season varies from one area of the country to another. May through October is typical but states in the south and southwest may monitor the entire year. Northern States would have shorter ozone seasons such as May through September for North Dakota. This analysis uses these ozone seasons on a State by State basis to ensure that the data completeness requirements apply to the relevant portions of the year.

The O_3 NAAQS is defined in terms of the daily maximum, that is, the highest hourly average for the day, and it specifies that the expected number of days per year with values greater than 0.12 ppm should not be greater than one. Both the annual second highest daily maximum and the number of daily exceedances during the ozone season are considered in this analysis.

The trends site selection process, discussed in Section 2.1, resulted in 388 sites being selected for the 1979-88 period, an increase of 114 sites (or 42%) from the 1978-87 trends data base. A total of 567 sites (45 more sites than in 1983-87) are included in the 1984-88 data base. The NAMS compose 165 of the long-term trends sites and 196 of the sites in the 5-year trends data base. In both cases, the 5-year data base is much larger than the 10-year data base, which reflects the growth in ambient ozone monitoring networks.

3.5.1 Long-term 0_3 Trends: 1979-88

Figure 3-32 displays the 10-year composite average trend for the second highest day during the ozone season for the 388 trends sites and the subset of 165 NAMS sites. The 1988 composite average for the 388 trend sites is 2 percent higher than the 1979 average, and 9 percent higher than the 1987 composite average. The 1988 composite average is less than 1 percent lower than 1983, which is the highest average during this ten year period, 1979-88. The relatively high ozone concentrations in both 1983 and 1988 are likely attributed in part to meteorological conditions in some areas of the country that were more conducive to ozone formation than other years.

The summer of 1988, with its very hot, dry weather and stagnant conditions, was highly conducive to peak ozone levels. Nationally, 1988 was the third hottest summer since 1931. In the north central states, it was the hottest summer in almost 60 years.[11] Unusually high ozone levels and numerous exceedances were reported beginning in early June. In response to public concern and media attention, EPA initiated a cooperative program with the state and local air pollution control agencies for the early reporting of ozone summary data.[12] During the 1988 survey, preliminary, unvalidated data were reported to EPA approximately 3 to 4 months ahead of the schedule typically required for quality assurance and data submittal. Data were obtained from a subset of 272 sites, which yielded a preliminary estimate of a 14 percent increase between 1987 and 1988 composite ozone levels.[13,14] The differences between the preliminary and current estimates, a 14 percent increase versus 9 percent, result from three primary factors: (1) revisions in the preliminary data due to quality assurance checks, (2) the use of interpolated 1987 ozone levels for missing 1988 data at 30 trend sites, and (3) the preliminary data for Region IX showed a greater increase than the full data set. The last factor is responsible for most of the difference given the large number of Region IX sites in the trends data base (about 25 percent). The four Region IX survey sites recorded an 11 percent increase, whereas the composite for the current 89 trend sites increased by only 2 percent. In contrast, the composite average for non-California sites increased by 12 percent between 1987 and 1988.

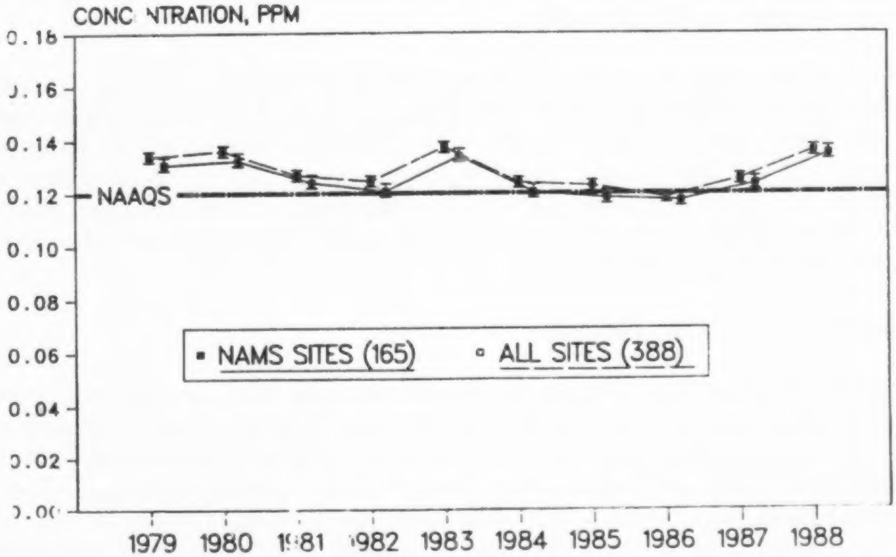

Figure 3-32. National trend in the composite average of the second highest maximum 1-hour ozone concentration at both NAMS and all sites with 95 percent confidence intervals, 1979-1988.

This same 10-year trend for the annual second highest daily maximum for the 388 site data base is displayed in Figure 3-33 by the boxplot presentation. The years 1979, 1980, 1983 and 1988 values are similarly high, while the remaining years in the 1979-87 period are generally lower, with 1986 being the lowest, on average. In 1987, ozone concentrations generally returned to the levels recorded during 1984 and 1985 except for the peak sites, which were considerably lower than these earlier years. Except for the 90th and 95th percentiles, all the remaining percentiles for 1988 are higher than the comparable percentiles in 1983. The median for 1988 is the highest in the 1980's and is almost one percent higher than the median for 1983. Figure 3-34 depicts the 1979-88 trend for the composite average number of ozone exceedances. This statistic is adjusted for missing data, and it reflects the number of days that the ozone standard is exceeded during the ozone season. Since 1979, the expected number of exceedances decreased 10 percent for the 388 sites and 4 percent for the 165 NAMS. Between 1987 and 1988, the composite average of the expected number of exceedances increased 38 percent. As with the second maximum, the 1979, 1980, 1983 and 1988 values are higher than the other years in the 1979-88 period.

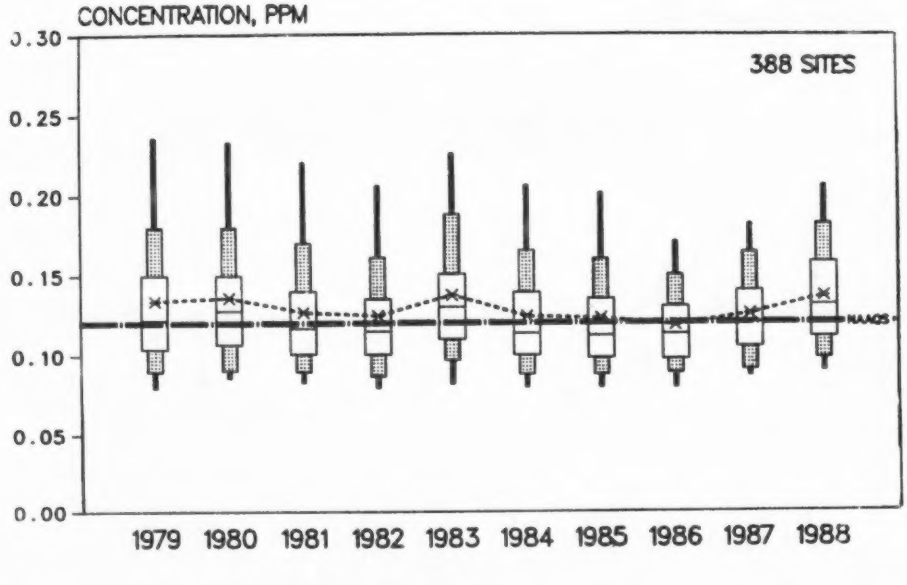

Figure 3-33. Boxplot comparisons of trends in annual second highest daily maximum 1-hour ozone concentration at 388 sites, 1979-1988.

Table 3-5 and Figure 3-35 display the 1979-88 emission trends for volatile organic compounds (VOC) which, along with nitrogen oxides, are involved in the atmospheric chemical and physical processes that result in the formation of O_3. Total VOC emissions are estimated to have decreased 17 percent between 1979 and 1988. Between 1979 and 1988, VOC emissions from highway vehicles are estimated to have decreased 28 percent, despite a 33 percent increase in vehicle miles of travel during this time period (see Figure 3-24).

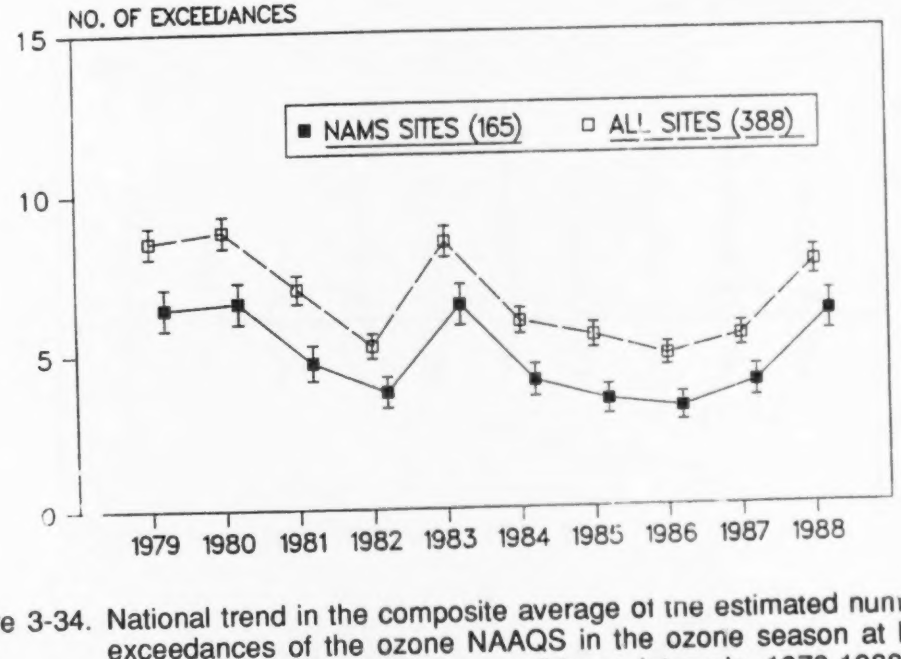

Figure 3-34. National trend in the composite average of the estimated number of daily exceedances of the ozone NAAQS in the ozone season at both NAMS and all sites with 95 percent confidence intervals, 1979-1988.

Table 3-5. National Volatile Organic Compound Emission Estimates, 1979-1988.

(million metric tons/year)

Source Category	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Transportation	8.0	7.5	7.4	7.2	7.1	7.2	6.9	6.5	6.4	6.1
Fuel Combustion	0.9	0.9	0.9	1.0	1.0	1.0	0.9	0.9	0.9	0.9
Industrial Processes	9.9	9.2	8.3	7.5	7.9	8.8	8.5	8.1	8.3	8.5
Solid Waste	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Miscellaneous	2.9	2.9	2.5	2.2	2.7	2.7	2.2	2.2	2.4	2.4
TOTAL	22.4	21.1	19.8	18.4	19.3	20.3	19.1	18.3	18.6	18.6

NOTE: The sums of sub-categories may not equal total due to rounding.

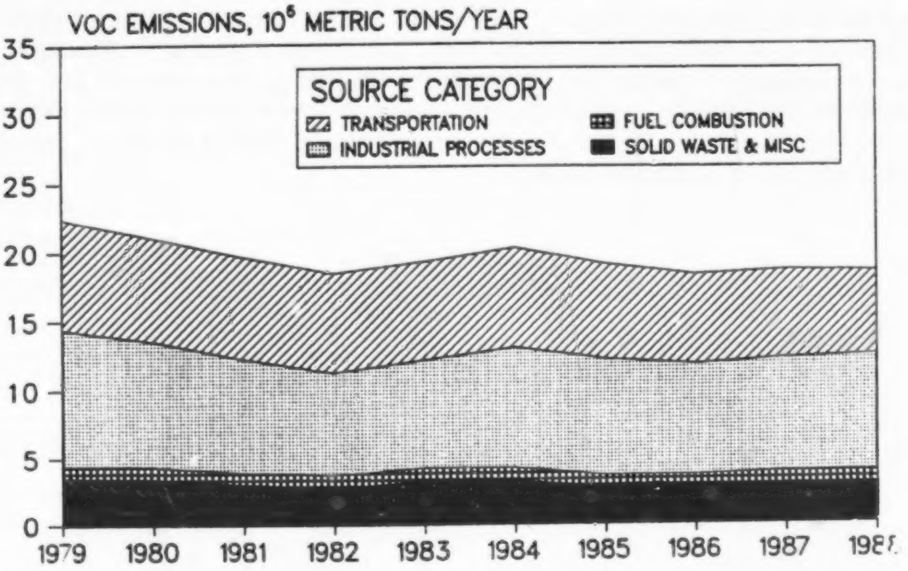

Figure 3-35. National trend in emissions of volatile organic compounds, 1979-1988.

3.5.2 Recent O_3 Trends: 1984-88

This section discusses ambient O_3 trends for the 5-year time period 1984-88. Using this period permits the use of a larger data base of 567 sites, compared to 388 for the 10-year period. Figure 3-36 uses a boxplot presentation of the annual second maximum daily value at these 567 sites. The national composite average increased 9 percent between 1984 and 1988. The composite average increased 8 percent from 1987 to 1988, likely due to the hot, dry meteorological conditions experienced in much of the Eastern U.S. during the last summer. The most obvious feature of Figure 3-36 is that 1988 levels were clearly higher than those of the other years. Table 3-5 indicates that total VOC emissions are estimated to have decreased by 8 percent during this period. However, these emissions estimates are annual totals based on annual average temperatures and may not reflect the possible impact of the above average temperatures on evaporative emissions during the past two summers.

The composite average of the second daily maximum concentrations increased in every region of the country. As Figure 3-37 indicates, the largest increases were recorded in the northeastern states, composing EPA Regions I through III. Figure 3-38 presents a Regional comparison for 1986, through 1988 of the composite average second highest daily maximum 1-hour ozone concentration. Except for Region VIII, the 1988 values were higher than in 1986 and 1987 in the remaining nine regions.

Studies have shown that peak ozone levels are highly correlated with maximum daily temperature and with the number of days with greater than 90 degrees Fahrenheit (°F).[15] Figure 3-39 uses the Regional bar chart format to present the number of days greater than 90° F in 1986-88 for selected cities in these Regions.[16] Although there is considerable similarity between the patterns for the air quality data (Figure 3-37) and the patterns for this simple meteorological indicator, peak ozone levels result from a complex process, and this single indicator may not be sufficient to adequately describe year-to-year variability in ozone levels.

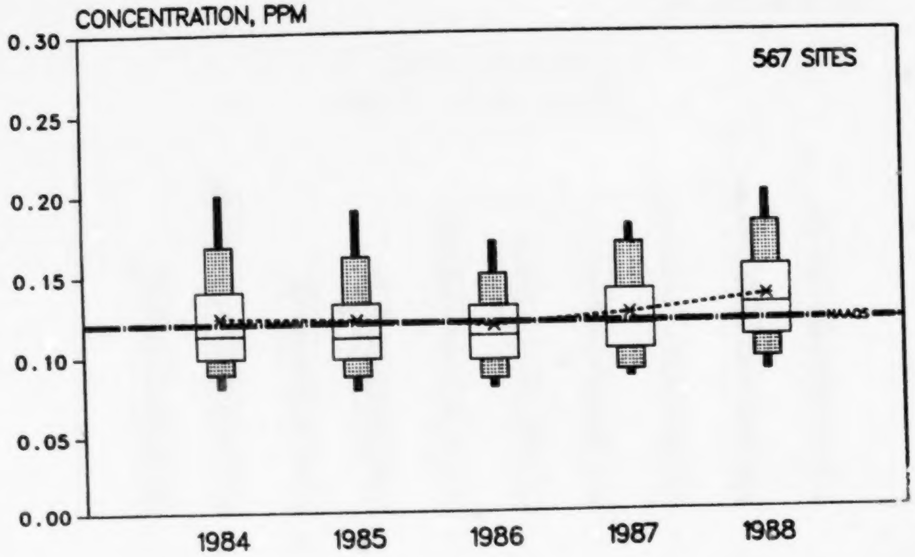

Figure 3-36. Boxplot comparisons of trends in annual second highest daily maximum 1-hour ozone concentrations at 567 sites, 1984-1988.

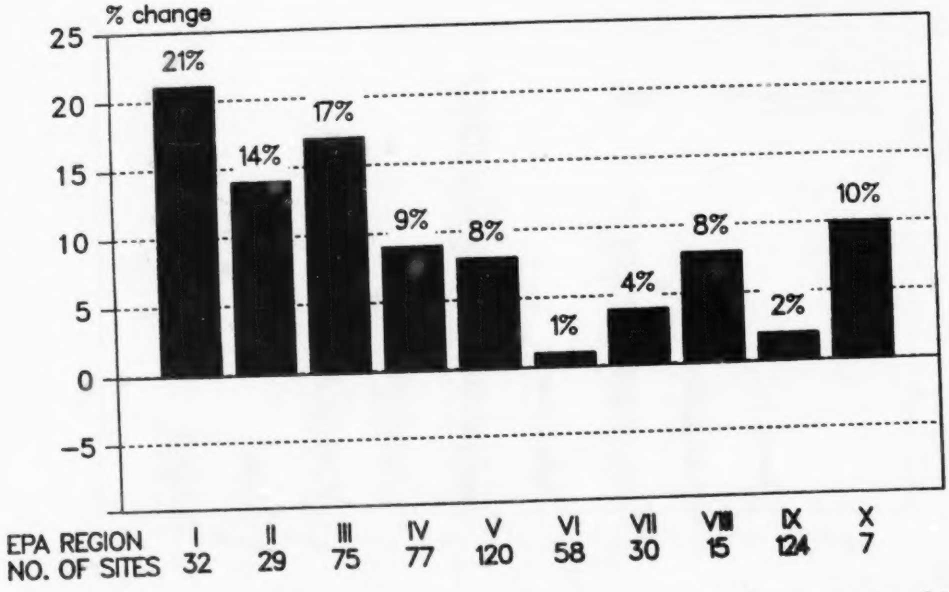

Figure 3-37. Regional comparison of percent increases in the average of the second daily maximum 1-hour concentration between 1987 and 1988.

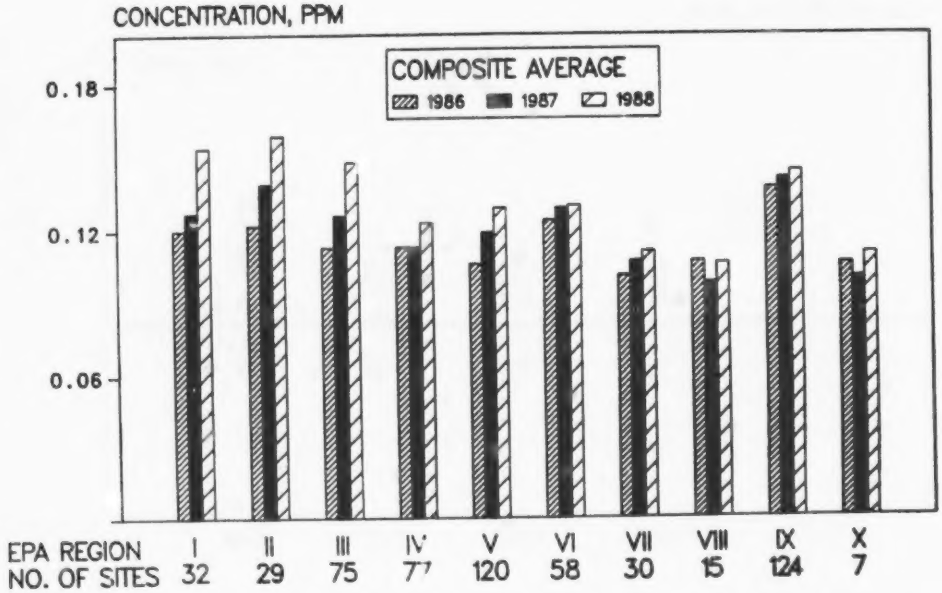

Figure 3-38. Regional comparisons of the 1986, 1987, 1988 composite averages of the second-highest daily 1-hour ozone concentrations.

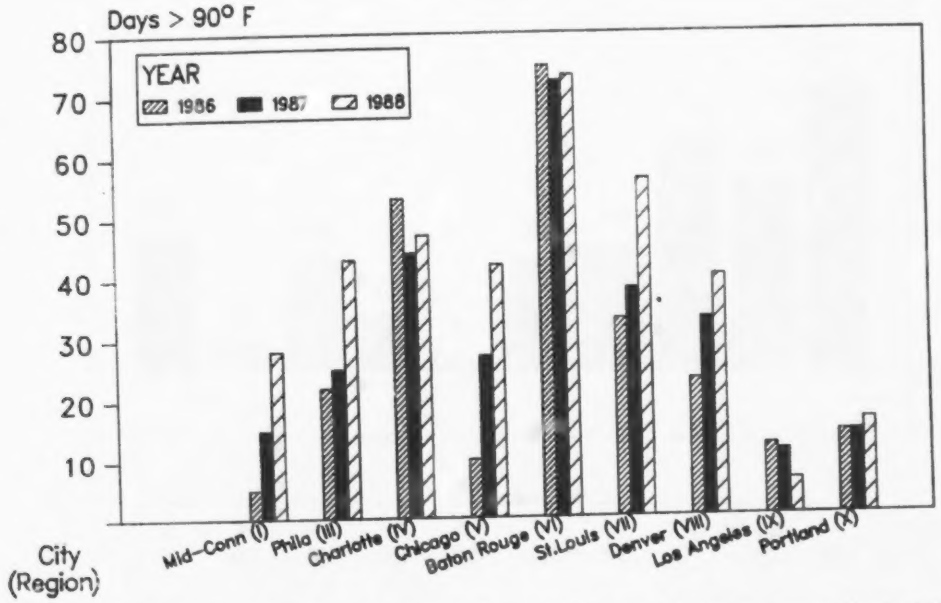

Figure 3-39. Regional comparisons of the number of days greater than 90°F in 1986, 1987, 1988 for selected cities.

3.5.4 Preview of 1989 Ozone Trends

The voluntary survey that was initiated in 1988 for the early reporting of preliminary, unvalidated ozone summary data was expanded in 1989 with 588 sites reporting on an accelerated schedule. Preliminary 1989 data indicate that the direction of the trend is that 1989 ozone levels are much lower than those of 1988. Data from the National Climatic Center indicate that in 1989 excessive rain replaced the drought as the weather phenomenon of the year.[17,18] In the rain-soaked East, the period from January through July was among the wettest on record in nine states. Maryland had more rain from January through July 1989 than in any other January through July period in the last 95 years. Only 1 year in the last 95 was wetter than 1989 in Delaware, Pennsylvania, Tennessee and West Virginia. Only 2 years were wetter in New Jersey and North Carolina, only 3 in Kentucky and only 4 in Ohio. The absence of favorable conditions for ozone formation in the eastern U.S. during summer 1989 is likely responsible for the decrease in ozone levels between 1988 and 1989. Recall that ozone is not emitted directly, but is formed in the atmosphere through a complex chemical reaction between volatile organic compounds and nitrogen oxides **in the presence of sunlight** and **higher temperatures**.

Figure 3-40 shows a preliminary estimate of the trend in the composite average of the annual daily maximum 1-hour concentration for the period 1979 through 1989. The 1989 composite average estimate is 15 percent lower than the 1988 level and is comparable to the 1986 level. This estimate is based on a subset of 311 of the 388 long-term trend sites and was adjusted for the mix of sites in the trends database. Although based on a larger number of sites than last year's preliminary 1988 estimate, this 1989 estimate should be viewed as preliminary, because the 1989 data have not yet been subjected to the complete quality assurance process.

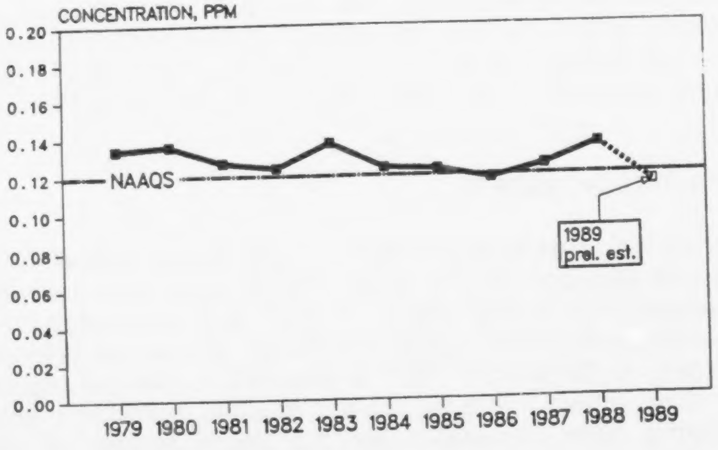

Figure 3-40. Preliminary estimate of the national trend in the composite average of the second highest daily maximum 1-hour ozone concentration, 1979-89.

3.6 TRENDS IN LEAD

Lead (Pb) gasoline additives, nonferrous smelters and battery plants are the most significant contributors to atmospheric Pb emissions. Transportation sources in 1988 contributed 34 percent of the annual emissions, down substantially from 73 percent in 1985. Total lead emissions from all sources dropped from 21.1 x 10^3 metric tons in 1985 to 8.0 x 10^3 and 7.6 x 10^3 metric tons, respectively in 1987 and 1988. The decrease in lead emissions from highway vehicles accounts for essentially all of this drop. The reasons for this drop are noted below.

Two air pollution control programs implemented by EPA before promulgation of the Pb standard in October 1978[19] have resulted in lower ambient Pb levels. First, regulations issued in the early 1970s required gradual reduction of the Pb content of all gasoline over a period of many years. Most recently the Pb content of the leaded gasoline pool was reduced from an average of 1.0 grams/gallon to 0.5 grams/gallon on July 1, 1985 and still further to 0.1 grams/gallon on January 1, 1986. Second, as part of EPA's overall automotive emission control program, unleaded gasoline was introduced in 1975 for use in automobiles equipped with catalytic control devices. These devices reduce emissions of carbon monoxide, volatile organics and nitrogen oxides. In 1988 unleaded gasoline sales accounted for 82 percent of the total gasoline market. These programs have essentially eliminated violations of the lead standard in urban areas, except in those areas with lead point sources. Programs are also in place to control Pb emissions from stationary point sources. Pb emissions from stationary sources have been substantially reduced by control programs oriented toward attainment of the TSP and Pb ambient standards, however, significant ambient problems still remain around some lead point sources. Lead emissions in 1988 from industrial sources, e.g. primary and secondary lead smelters dropped by more than one-half from levels reported in the late 70s. Emissions of lead from solid waste disposal are down 38 percent since the late 70s. In 1988 emissions from solid waste disposal (2.5 x 10^3 metric tons) represent the second largest category of lead emissions just behind the 2.6 x 10^3 metric tons from transportation. The overall effect of these three control programs has been a major reduction in the amount of Pb in the ambient air.

3.6.1 Long-term Pb Trends: 1979-88

Early trend analyses of ambient Pb data[20,21] were based almost exclusively on National Air Surveillance Network (NASN) sites. These sites were established in the 1960's to monitor ambient air quality levels of TSP and associated trace metals, including Pb. The sites were predominantly located in the central business districts of larger American cities. In September 1981, ambient Pb monitoring regulations were promulgated.[22] The siting criteria in the regulations resulted in finding many of the old historic TSP monitoring sites unsuitable for the measurement of ambient Pb concentrations and many of the earlier sites were moved or discontinued.

As with the other pollutants, the sites selected for the long-term trend analysis had to satisfy annual data completeness criteria of at least 8 out of 10 years of data in the 1979 to 1988 period. A year was included as "valid" if at least 3 of the 4 quarterly averages were available. As in last year's report, composite lead data, i.e., individual 24-hour observations are composited together by month or quarter and a single analysis made, are being used in the trend analysis. Thirty-seven sites qualified for the 10-year trend because of the addition of composite data. Eighty-six additional sites qualified for the 5-year trend, which will be discussed later. A total of 139 urban-oriented sites, representing 30 States, met the data completeness criteria. Twenty-nine of these sites were NAMS, the largest number of lead NAMS sites to qualify for the 10-year criteria. Twenty-four (17 percent) of the 139 trend sites were located in the State of California, thus this State is over-represented in the sample of sites satisfying the long-term trend criteria. However, the lead trend at the California sites was almost identical to the trend at the non-California sites; so that these sites did not distort the overall trends. Sites that were located near lead point sources such as primary and secondary lead smelters were excluded from the urban trend analysis, because the magnitude of the levels at these sources could mask the underlying urban trends. Trends at lead point source oriented sites will be discussed separately in the next section.

The means of the composite maximum quarterly averages and their respective 95 percent confidence intervals are shown in Figure 3-41 for both the 139 urban sites and 29 NAMS sites (1979-1988). There was an 89 percent (1979-88) decrease in the average for the 139 urban sites. Lead emissions over this 10-year period also decreased. There was a 93 percent decrease in total lead emissions and a 97 percent decrease in lead emissions from transportation sources. The confidence intervals for these sites indicate that the 1979-80 averages are significantly different from the 1981-88 averages. Because of the smaller number (29) of NAMS sites with at least 8 years of data, the confidence intervals are wider. However, the 1986-88 averages are still significantly different from all averages before 1985. It is interesting to note that the average lead concentrations at the NAMS sites in 1988 are essentially the same (0.084 vs. 0.085 $\mu g/m^3$) as the "all sites" average; whereas in the late 70s the average of the NAMS sites was significantly higher. Figure 3-42 shows the trend in average lead concentrations for the urban-oriented sites and for 18 point-source oriented sites which met the 10-year data completeness criteria. The improvement in average ambient lead concentrations at the point-source oriented sites, which are near industrial sources of lead, e.g. smelters, battery plants, is about the same on a percentage basis as the urban oriented sites. However, the average at the point-source oriented sites dropped in magnitude from 2.9 to 0.4 $\mu g/m^3$ a 2.5 difference; whereas, the average at the urban site dropped only from 0.8 to 0.1 $\mu g/m^3$. This improvement at the point-source oriented reflects both industrial and automotive lead emission controls, but in some cases, the industrial source reductions are because of plant shutdowns. Figure 3-43 shows boxplot comparisons of the maximum quarterly average Pb concentrations at the 139 urban-oriented Pb trend sites (1979-88). This figure shows the dramatic improvement in ambient Pb concentrations for the entire distribution of trend sites. As with the composite average concentration since 1979, most of the percentiles also show a monotonically decreasing pattern. The 139 urban-oriented sites that qualified for the 1979-88 period, when compared to the 97 sites for the 1978-87 period in last year's report,[14] indicate an expansion of the trends data base in more recent years.

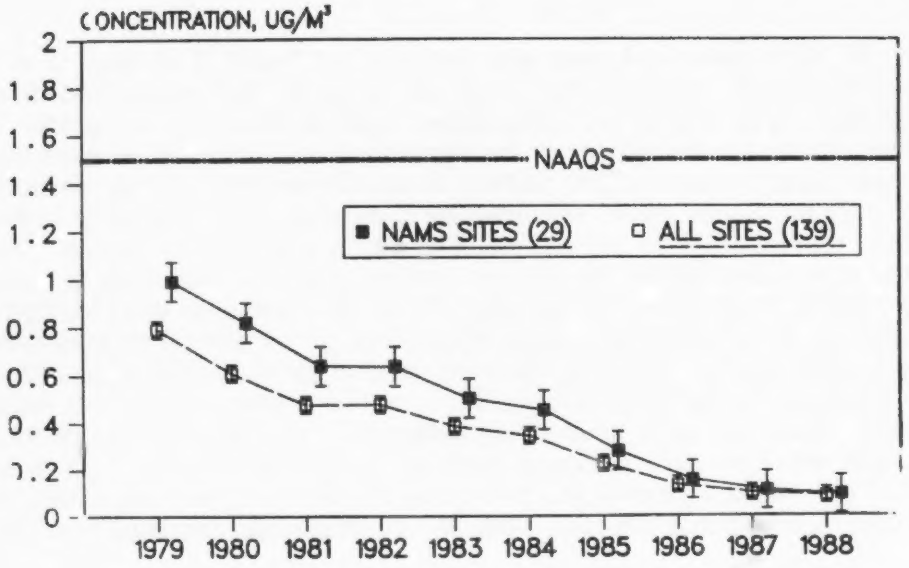

Figure 3-41. National trend in the composite average of the maximum quarterly average lead concentration at 139 sites and 29 NAMS sites with 95 percent confidence intervals, 1979-1988.

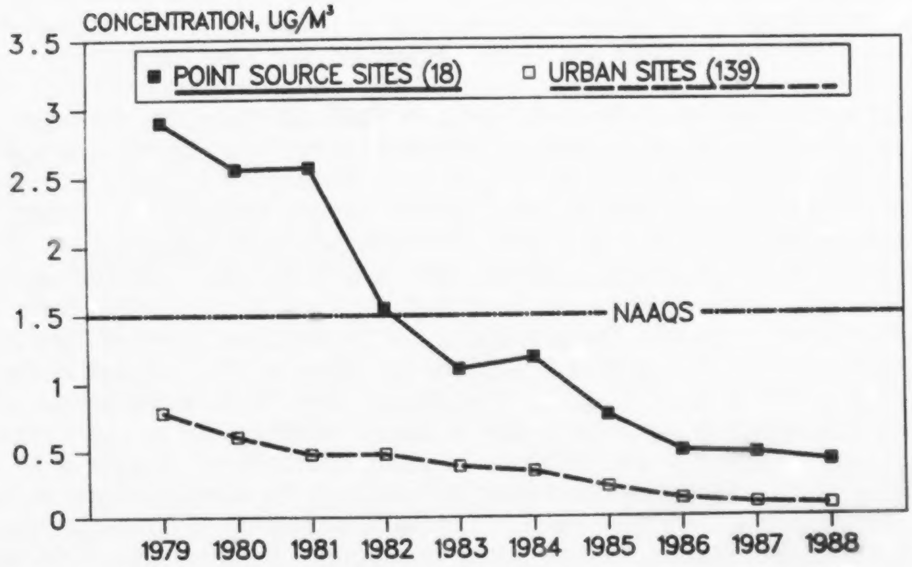

Figure 3-42. Comparison of national trend in the composite average of the maximum quarterly average lead concentrations at urban and point-source oriented sites, 1979-1988.

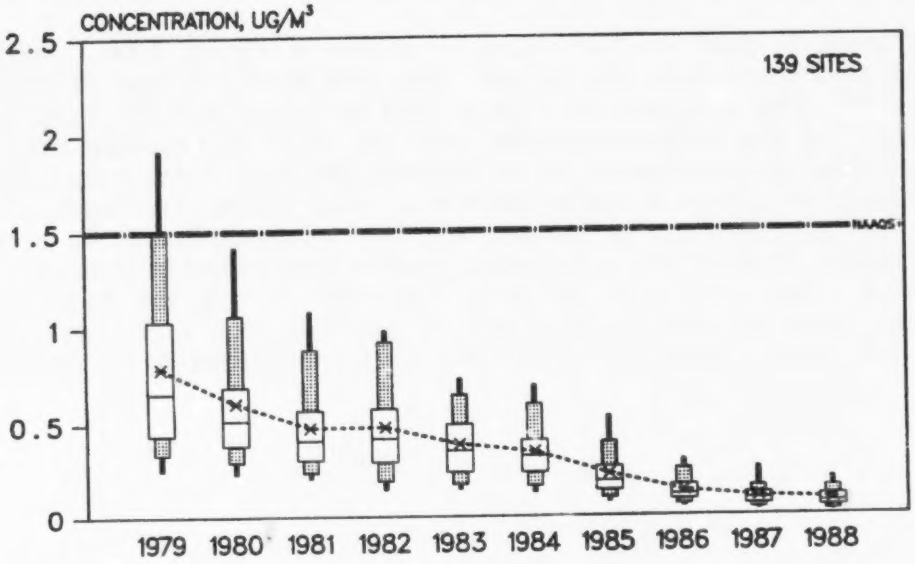

Figure 3-43. Boxplot comparisons of trends in maximum quarterly average lead concentrations at 139 sites, 1979-1988.

The trend in total lead emissions is shown in Figure 3-44. Table 3-6 summarizes the Pb emissions data as well. The 1979-88 drop in total Pb emissions was 93 percent. This compares with a 89 percent decrease (1979-88) in ambient Pb noted above. The drop in Pb consumption and subsequent Pb emissions since 1979 was brought about by the increased use of unleaded gasoline in catalyst-equipped cars and the reduced Pb content in leaded gasoline as noted above. The results of these actions in 1988 amounted to a 64 percent reduction nationwide in total Pb emissions from 1985 levels. As noted above, unleaded gasoline represented 82 percent of 1988 total gasoline sales. Although the good agreement among the trend in lead consumption, emissions and ambient levels is based upon a limited geographical sample, it does show that ambient urban Pb levels are responding to the drop in lead emissions.

Table 3-6. National Lead Emission Estimates, 1979-1988.

(thousand metric tons/year)

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Source Category										
Transportation	94.6	59.4	46.9	46.9	40.8	34.7	15.5	3.5	3.0	2.6
Fuel Combustion	4.9	3.9	2.8	1.7	0.6	0.5	0.5	0.5	0.5	0.5
Industrial Processes	5.2	3.6	3.0	2.7	2.4	2.3	2.3	1.9	1.9	2.0
Solid Waste	4.0	3.7	3.7	3.1	2.6	2.6	2.8	2.7	2.6	2.5
Total	108.7	70.6	56.4	54.4	46.4	40.1	21.1	8.6	8.0	7.6

NOTE: The sums of sub-categories may not equal total due to rounding.

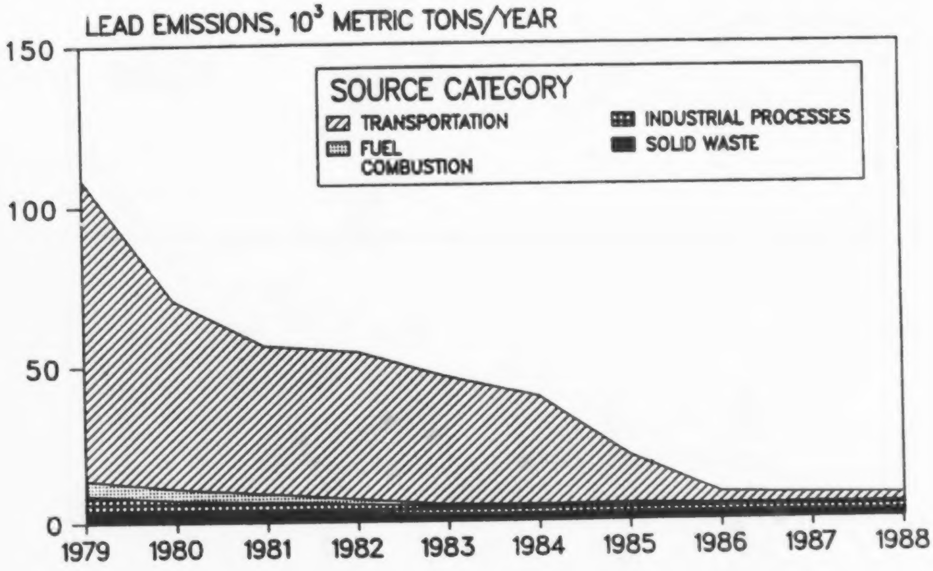

Figure 3-44. National trend in lead emissions, 1979-1988.

3.6.2 Recent Pb Trends: 1984-88

Ambient Pb trends were also studied over the shorter period 1984-88 (Figure 3-45). A total of 343 urban sites in 44 States met the minimum data requirement of at least 4 out of the 5 years of data. The number of sites qualifying for the 5-year trend data base is down about 50 from last years' report. This drop ensues because of the elimination of some TSP monitors from State and local air monitoring programs. Some monitors were eliminated due to the change in the particulate matter standard from TSP to PM_{10} while others were discontinued because of the very low lead concentrations measured in many urban locations. Although some further attrition may occur, the core network of NAMS lead sites together with supplementary State and local sites should be sufficient to access national ambient lead trends. This larger and more representative set of sites showed an improvement of 76 percent in average Pb concentrations during this time period. This corresponds to reductions in total Pb emissions of 81 percent and a reduction of 93 percent in lead emissions from transportation sources. Most of this decrease in total nationwide Pb emissions, 99 percent, was due to the decrease in automotive Pb emissions. Even this larger group of sites was disproportionately weighted by sites in California, Illinois, and Texas. These States had about 30 percent of the 343 sites represented. However, the percent changes in 1984-88 average Pb concentrations for these three States were very similar to the percent change for the remaining sites, thus the contributions of these sites did not distort the national trends.

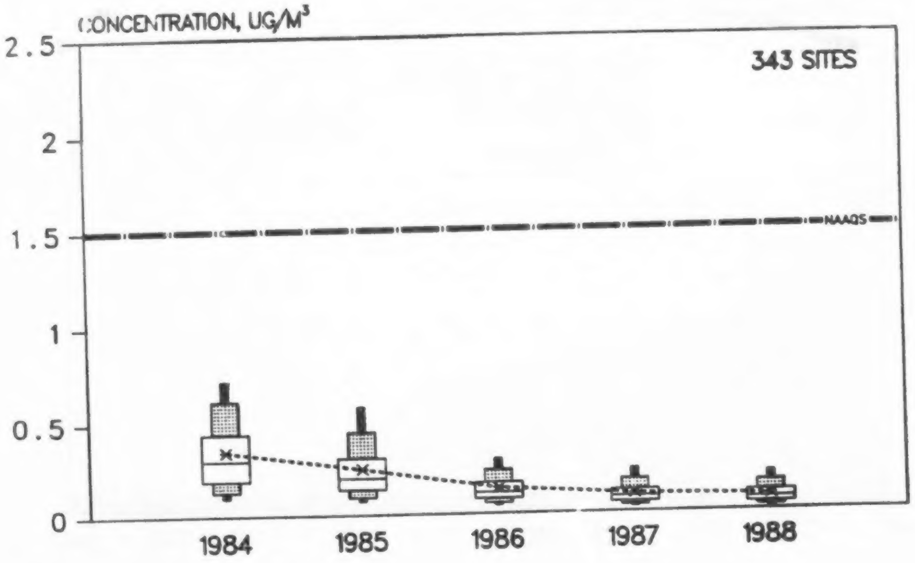

Figure 3-45. Boxplot comparisons of trends in maximum quarterly average lead concentrations at 343 sites, 1979-1988.

Indeed, as will be shown later, all sections of the country are showing declines in average lead concentrations. Fifty-eight (58) point source oriented sites showed an average drop of 36 percent over the 1984-88 time period. Thus, the decrease in ambient lead concentrations near lead point sources has been less pronounced than in urban areas. It is worth noting that the sites in the 10-year data base also showed a 75 percent decrease during this 5-year period, suggesting that, despite the geographical imbalance, their patterns may adequately depict national trends.

Because of the much larger sample of sites represented in the 5-year trends (1984-88), compared with the 10-year, the larger sample will be used to compare the more recent individual yearly averages. The largest single year drop in average lead concentrations, 44 percent, occurs as expected between 1985 and 1986, because of the shift of the lead content in leaded gasoline. 1988 average lead concentrations show the more modest decline of 15 percent from 1987 levels. Examining only the 266 sites which had data in both 1987 and 1988, revealed a 17 percent decrease in average lead concentrations which is almost the same as when the 5-year trends data base is used. Lead emissions between 1987 and 1988 decreased both for the total (5 percent) and from only transportation sources (13 percent). This trend is expected to continue primarily because the leaded gasoline market will continue to shrink. Some major petroleum companies have discontinued refining leaded gasoline because of the dwindling market, so that in the future the consumer may find it more difficult to purchase regular leaded gasoline.

Figure 3-46 shows 1986, 1987 and 1988 composite average Pb concentrations, by EPA Region. Once again the larger more representative 5-year data base of 343 sites was used for comparison. The number of sites varies dramatically by Region from 8 in Region VIII to 76 in Region V. In all Regions, there is a decrease in average Pb urban concentrations between 1986 and 1988. These results confirm that average Pb concentrations in urban areas are continuing to decrease in all sections of the country, which is exactly what is to be expected because of the national air pollution control program for Pb.

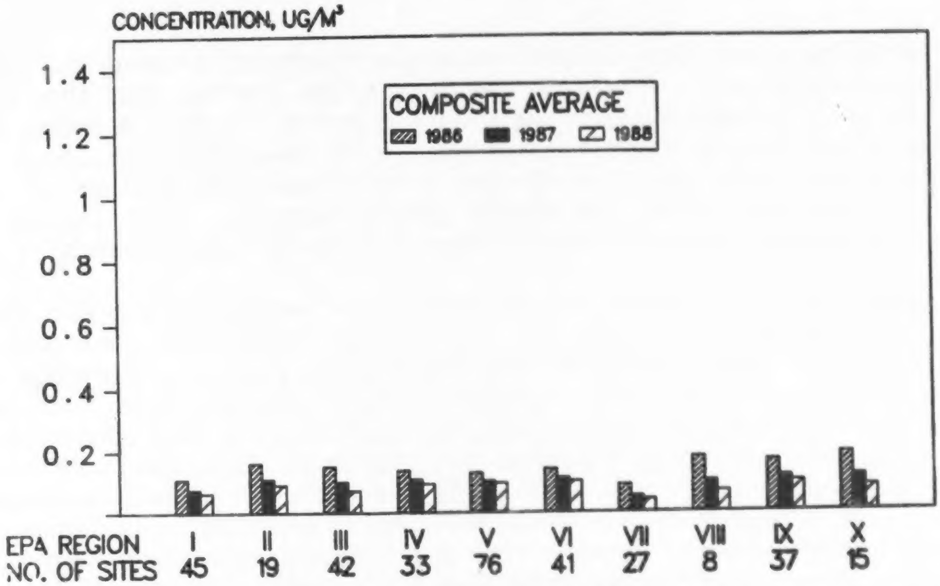

Figure 3-46. Regional comparison of the 1986, 1987, 1988 composite average of the maximum quarterly average lead concentration.

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4. AIR QUALITY STATUS OF METROPOLITAN AREAS, 1988

This chapter provides general information on the current air quality status of metropolitan areas[1] within the United States. Four different summaries are presented in the following sections. First, maps depicting the metropolitan areas failing to meet the National Ambient Air Quality Standards (NAAQS) for ozone and carbon monoxide standards are presented. Next, an estimate is provided of the number of people living in counties which did not meet the NAAQS based on 1988 air quality data. Third, pollutant-specific maps are presented to provide the reader with a geographical view of how peak 1988 air quality levels varied throughout the 90 largest Metropolitan Statistical Areas (MSAs) in the continental United States. Finally, the peak pollutant-specific statistics are listed for each MSA with 1988 air quality monitoring data.

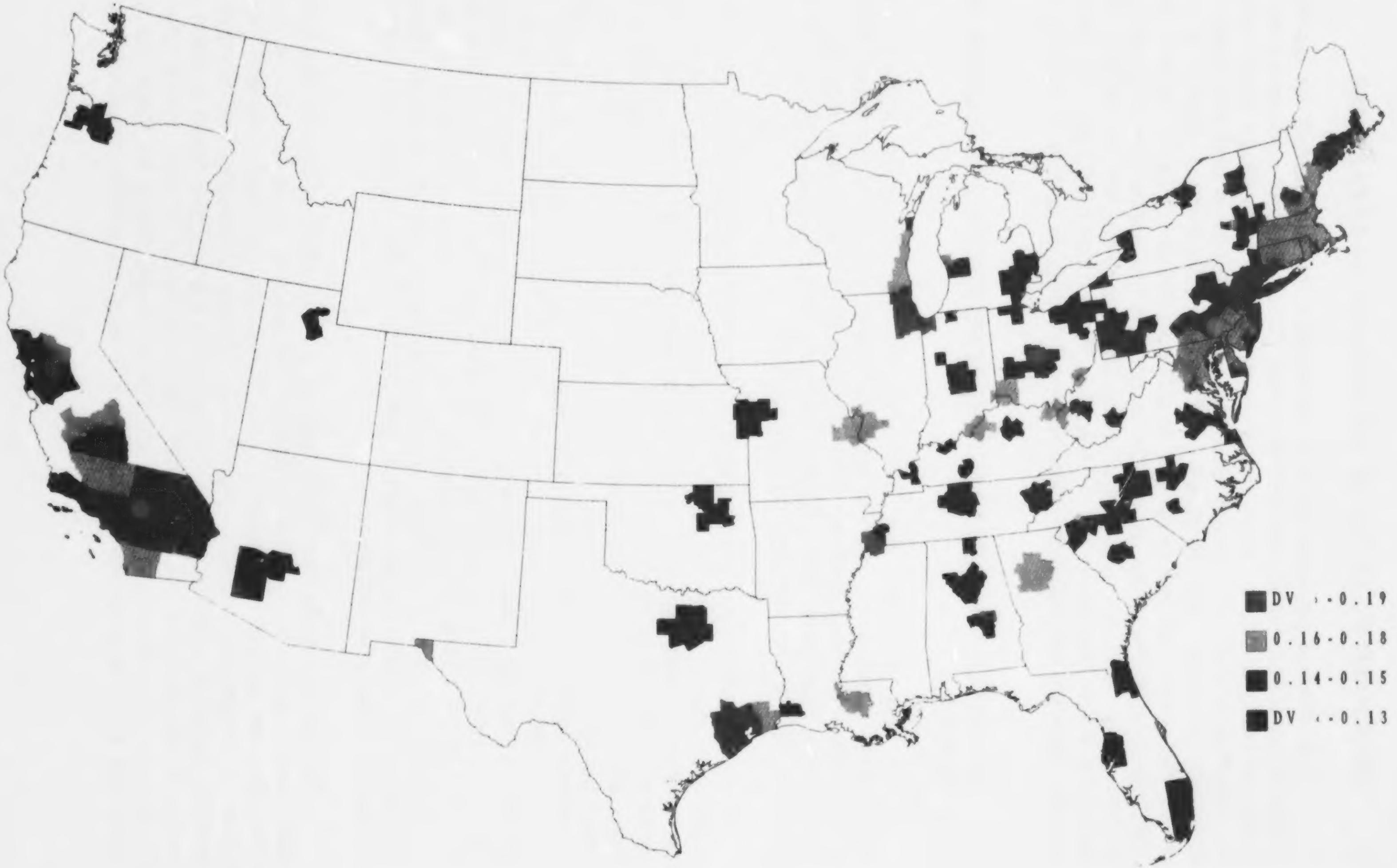
4.1 METROPOLITAN AREAS NOT MEETING OZONE AND CARBON MONOXIDE NAAQS

On July 27, 1989 the U.S. Environmental Protection Agency listed[2] those metropolitan areas which failed to meet the ozone and carbon monoxide NAAQS based on ambient monitoring data for 1986 through 1988. The areas include Consolidated Metropolitan Statistical Areas (CMSA), which are composed of groups of MSAs, and individual MSAs and non-metropolitan counties.

Attainment of the ozone standard is determined using the three most recent years of air quality monitoring data. These data showed that 101 areas, mostly major metropolitan areas, failed to meet the ozone standard for the years 1986-88, an increase of 37 areas as compared to the 1985-87 period. All but one of these new areas are located east of the Mississippi River. The sharp increase in the number of areas failing to meet the ozone standard likely resulted from the hot, dry, stagnant conditions which dominated Summer 1988 in the eastern U.S. Nationally, 1988 was the third hottest summer since 1931. Figure 4-1, "Areas Exceeding the Ozone NAAQS Based on 1986-88 Data," displays the 101 areas failing to meet the ozone standard based on 1986-88 monitoring data. The areas on the map are shaded according to the level of the ozone design value for that area. The ozone design value serves as an indicator of the magnitude of the problem in terms of peak concentrations. Typically, the ozone design value would be the fourth highest daily maximum value during the three year period.

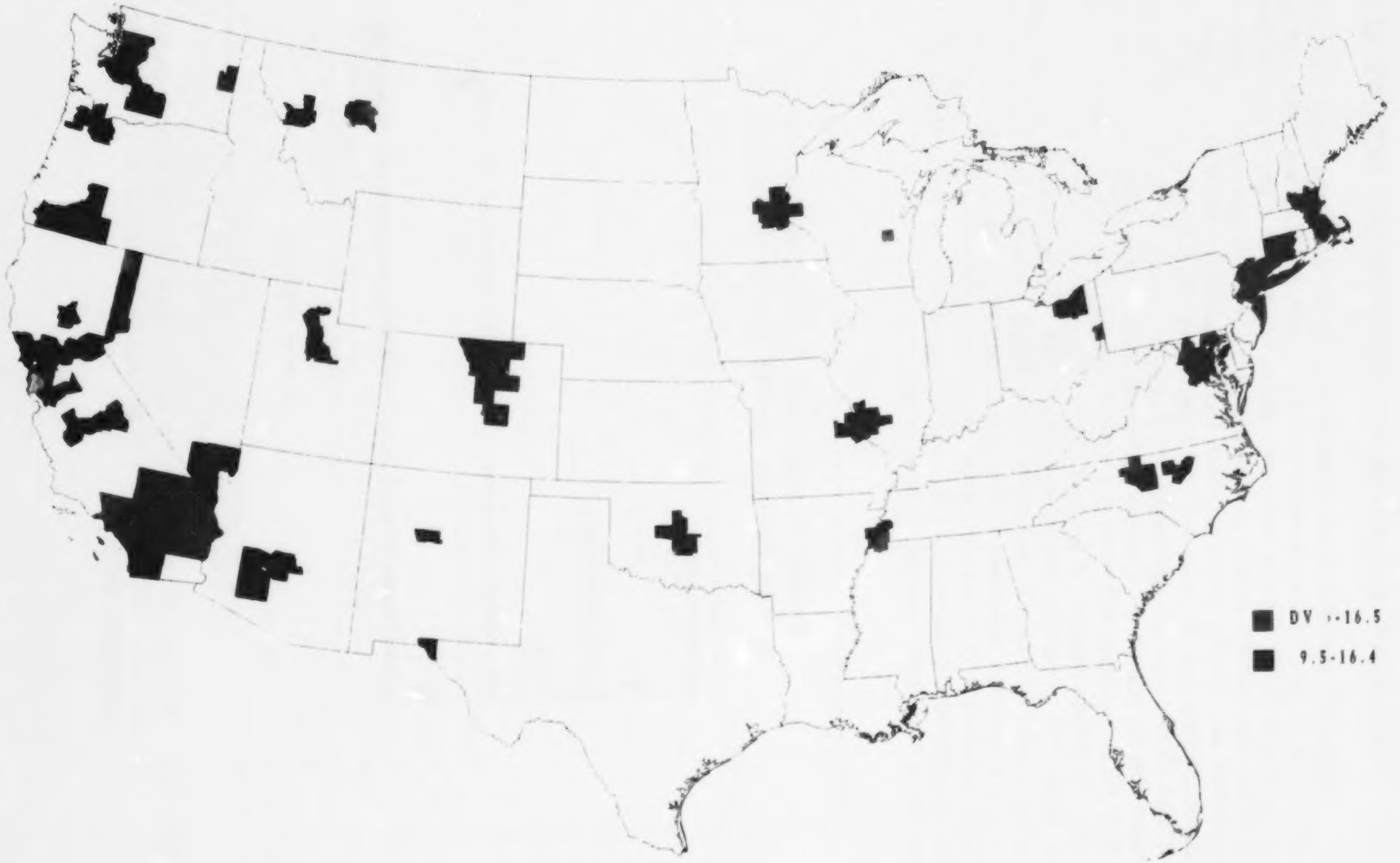
For carbon monoxide, attainment of the standard is determined using the two most recent years of monitoring data. The design value for CO is evaluated by computing the second maximum 8-hour concentration for each year and then using the higher of these two values. Figure 4-2, "Areas Exceeding the Carbon Monoxide NAAQS Based on 1987-88 Data," shows the 44 areas that failed to meet the carbon monoxide standard for the years 1987-88, a decrease of eight areas from the 1986-87 period. This decrease in the number of areas failing to meet the standard is consistent with the long-term improvement in ambient carbon monoxide levels.

AREAS EXCEEDING THE OZONE NAAQS
BASED ON 1986-88 DATA


DV >=0.19
0.16-0.18
0.14-0.15
DV <=0.13

AREAS EXCEEDING THE CARBON MONOXIDE NAAQS

BASED ON 1987-88 DATA


■ DV >=16.5
■ 9.5-16.4

4.2 POPULATION ESTIMATES FOR COUNTIES NOT MEETING NAAQS, 1988

Figure 4-3 provides an estimate of the number of people living in counties in which the levels of the pollutant-specific primary health NAAQS were not met by measured air quality in 1988. These estimates use a single-year interpretation of the NAAQS to indicate the current extent of the problem for each pollutant. Table 4-1 lists the selected air quality statistics and their associated NAAQS. Figure 4-3 clearly demonstrates that O_3 was the most pervasive air pollution problem in 1988 for the United States with an estimated 111.9 million people living in counties which did not meet the O_3 standard. Carbon monoxide follows, with 29.5 million people; PM_{10} with 25.6 million people; NO_2 with 8.3 million people; SO_2 with 1.7 million people; and Pb with 1.6 million people. A total of 121 million persons resided in counties not meeting at least one air quality standard during 1988. In contrast to the last annual report which used 1980 county population data, these estimates are based on current 1986 county population estimates. Thus, the 6 percent growth in total U.S. population since 1980 is reflected in these estimates. Also, the estimate for PM_{10} is considered a lower bound estimate, because the PM_{10} monitoring network is still evolving and the required sampling schedules are being determined.

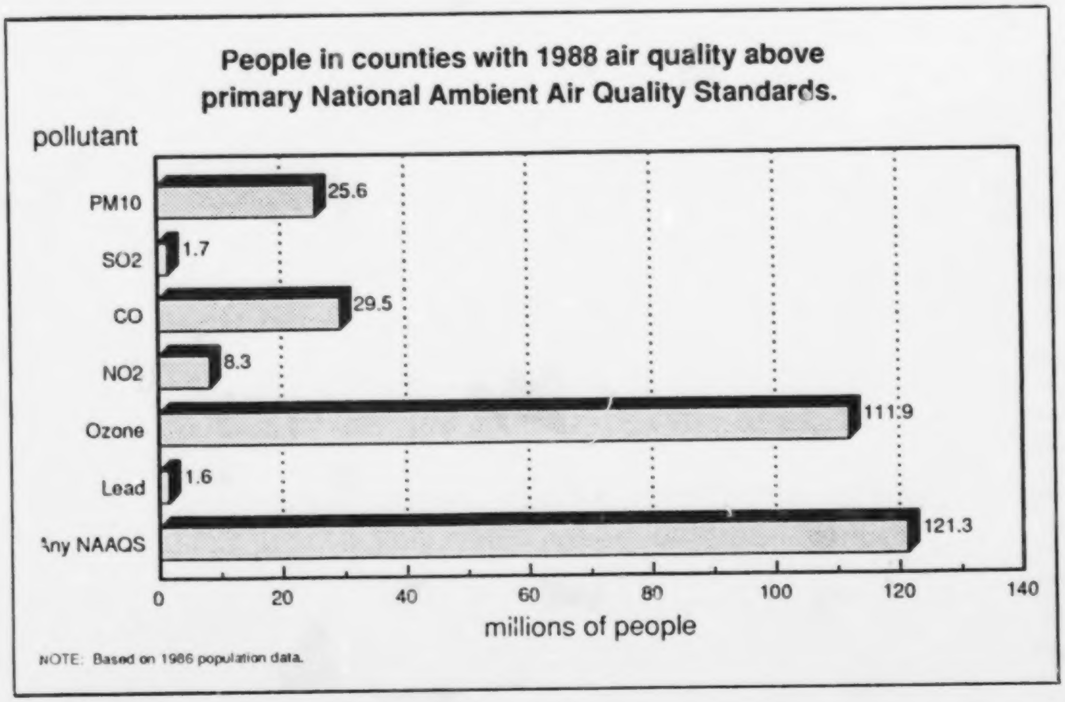


Figure 4-3. Number of persons living in counties with air quality levels above the primary national ambient air quality standards in 1988 (based on 1986 population data).

These population estimates are intended to provide a relative measure of the extent of the problem for each pollutant. The limitations of this indicator should be recognized. An individual living in a county that violates an air quality standard may not actually be exposed to unhealthy air. For example, if CO violations were confined to a traffic-congested center city location during evening rush hours in the winter, it is possible that an individual may never be in that area, or may be there only at other times of the day or during other seasons. However, it is worth noting that ozone, which appears to be the most pervasive pollution problem by this measure, is also the pollutant most likely to have fairly uniform concentrations throughout an area.

Table 4-1. Selected Air Quality Summary Statistics and Their Associated National Ambient Air Quality Standards (NAAQS)*

POLLUTANT	STATISTICS	PRIMARY NAAQS
Particulate Matter (PM_{10})	annual arithmetic mean	50 ug/m^3
Sulfur Dioxide (SO_2)	annual arithmetic mean	0.03 ppm
	second highest 24-hour average	0.14 ppm
Carbon Monoxide (CO)	second highest nonoverlapping 8-hour average	9 ppm
Nitrogen Dioxide (NO_2)	annual arithmetic mean	0.053 ppm
Ozone (0_3)	second highest daily maximum 1-hour average	0.12 ppm
Lead (Pb)	maximum quarterly average	1.5 ug/m^3

µg/m^3 = micrograms per cubic meter ppm = parts per million

*Single year interpretation. For a detailed listing of the NAAQS see Table 2-1.

4.3 AIR QUALITY LEVELS IN METROPOLITAN STATISTICAL AREAS

This section provides information for general air pollution audiences on 1988 air quality levels in each Metropolitan Statistical Area (MSA) in the United States. For those large MSAs with populations greater than 500,000, the 1988 annual air quality statistics are also displayed geographically on three-dimensional maps.

The general concept of a metropolitan area is one of a large population center, with adjacent communities which have a high degree of economic and social integration with the urban center. Metropolitan Statistical Areas contain a central county(ies), and any adjacent counties with at least 50 percent of their population in the urbanized area.[1] Although MSAs compose only 16 percent of the land area in the U.S., they account for 77 percent of the population. Table 4-2 displays the population distribution of the 339 MSAs, based on 1987 population estimates.[1] The New York, NY MSA is the nation's largest metropolitan area with a 1987 population in excess of 8 million. The smallest MSA is Enid, OK with a population of 60,000.

TABLE 4-2. Population Distribution of Metropolitan Statistical Areas Based on 1987 Population Estimates

Population Range	Number of MSAs	Total Population
≤ 100,000	27	2,274,000
100,000 < population ≤ 250,000	147	23,372,000
250,000 < population ≤ 500,000	73	25,218,000
500,000 < population ≤ 1,000,000	48	34,367,000
1,000,000 < population ≤ 2,000,000	26	38,685,000
population > 2,000,000	18	65,747,000
Total	339	189,663,000

4.3.1 Metropolitan Statistical Area Air Quality Maps, 1988

Figures 4-4 through 4-10 introduce air quality maps of the United States that show at a glance how air quality varies among the largest MSAs within the contiguous United States. To enable the reader to distinguish individual urban areas, only the 90 MSAs within the continental U.S. having populations greater than 500,000 are shown. Two large MSAs, Honolulu, HI and San Juan, PR are not shown. In each map, a spike is plotted at the city location on the map surface. This represents the highest pollutant concentration recorded in 1988, corresponding to the appropriate air quality standard. Each spike is projected onto a back-drop for comparison with the level of the standard. The backdrop also provides an east-west profile of concentration variability throughout the country.

The map for PM_{10} shows the 1988 maximum annual arithmetic means in metropolitan areas greater than 500,000 population. Concentrations above the level of the annual mean PM_{10} standard of 50 ug/m^3 are found in fourteen of these metropolitan areas (Figure 4-4).

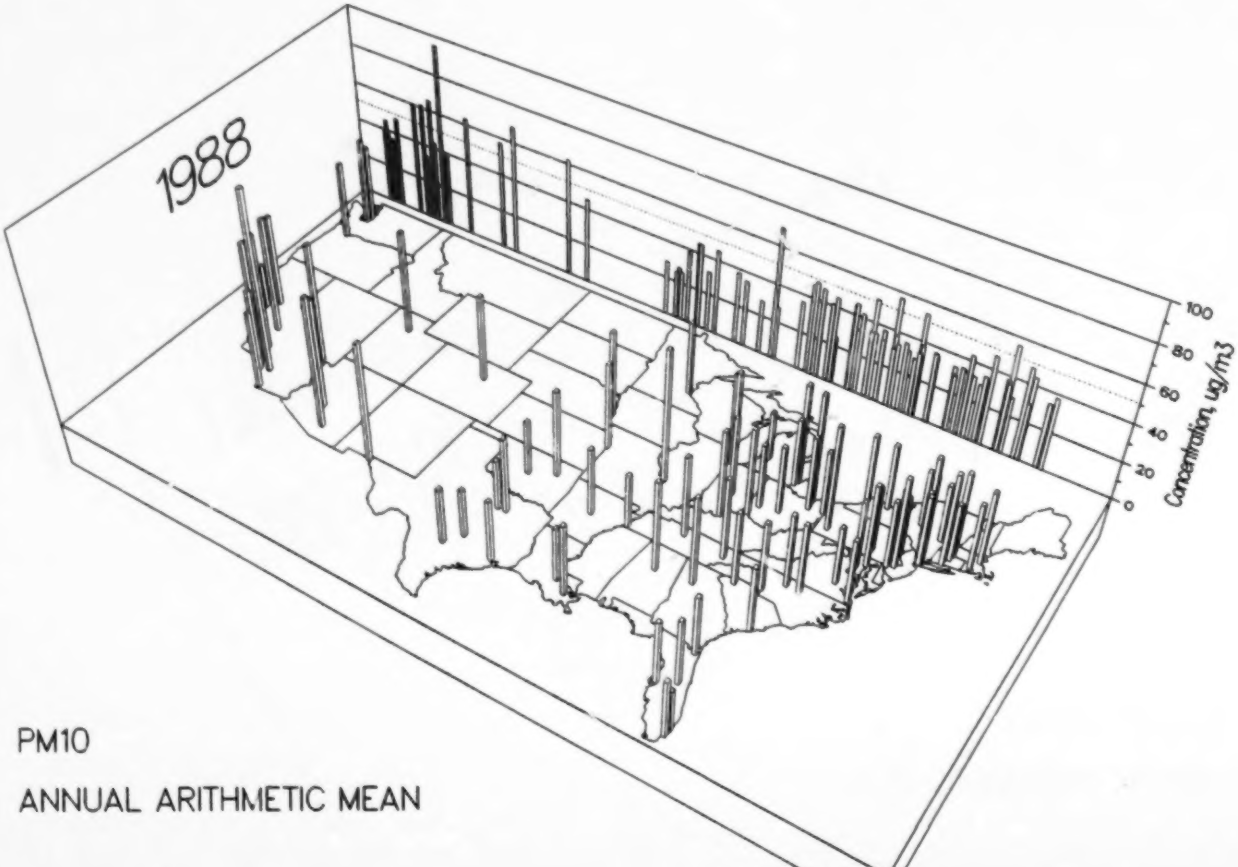

1988
100
80
60
40
20
0
Concentration, ug/m3
PM10
ANNUAL ARITHMETIC MEAN

Figure 4-4. United States map of the highest annual arithmetic mean PM_{10} concentration by MSA, 1988.

The map for sulfur dioxide shows maximum annual mean concentrations in 1988. Among these large metropolitan areas, the higher concentrations are found in the heavily populated Midwest and Northeast and near point sources in the west. All these large urban areas have ambient air quality concentrations lower than the current annual standard of 80 ug/m^3 (0.03 ppm). Because this map only represents areas with population greater than one half million, it does not reflect air quality in the vicinity of smelters or large power plants in rural areas (Figure 4-5).

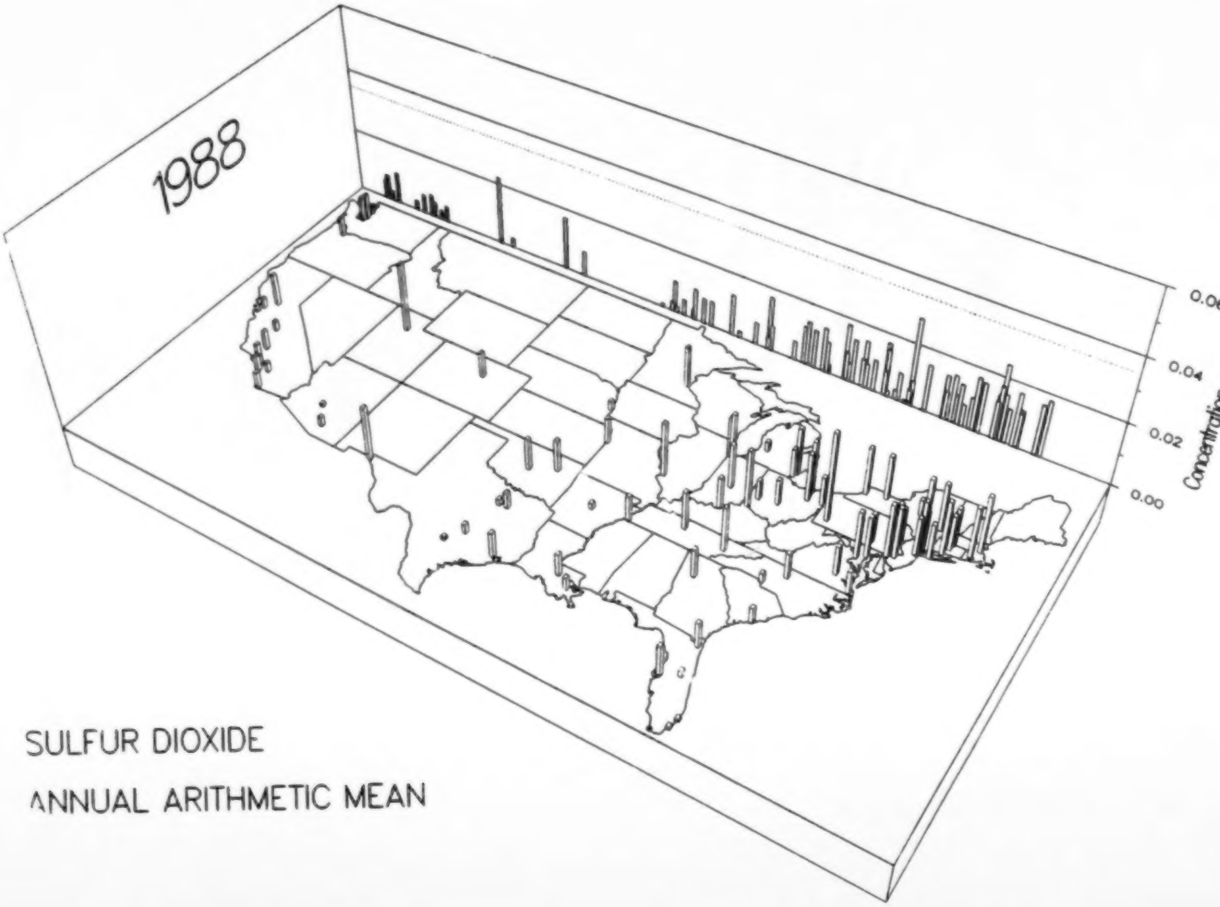

1988
0.06
0.04
0.02
0.00
Concentration, ppm
SULFUR DIOXIDE
ANNUAL ARITHMETIC MEAN

Figure 4-5. United States map of the highest annual arithmetic mean sulfur dioxide concentration by MSA, 1988.

The map for sulfur dioxide shows the highest second highest 24-hour average sulfur dioxide concentration by MSA in 1988. Among these large urban areas, only a site in Pittsburgh, PA which is impacted by major SO_2 sources, exceeds the standard. All other major urban areas have ambient concentrations below the 24-hour NAAQS of 365 ug/m^3 (0.14 ppm) (Figure 4-6).

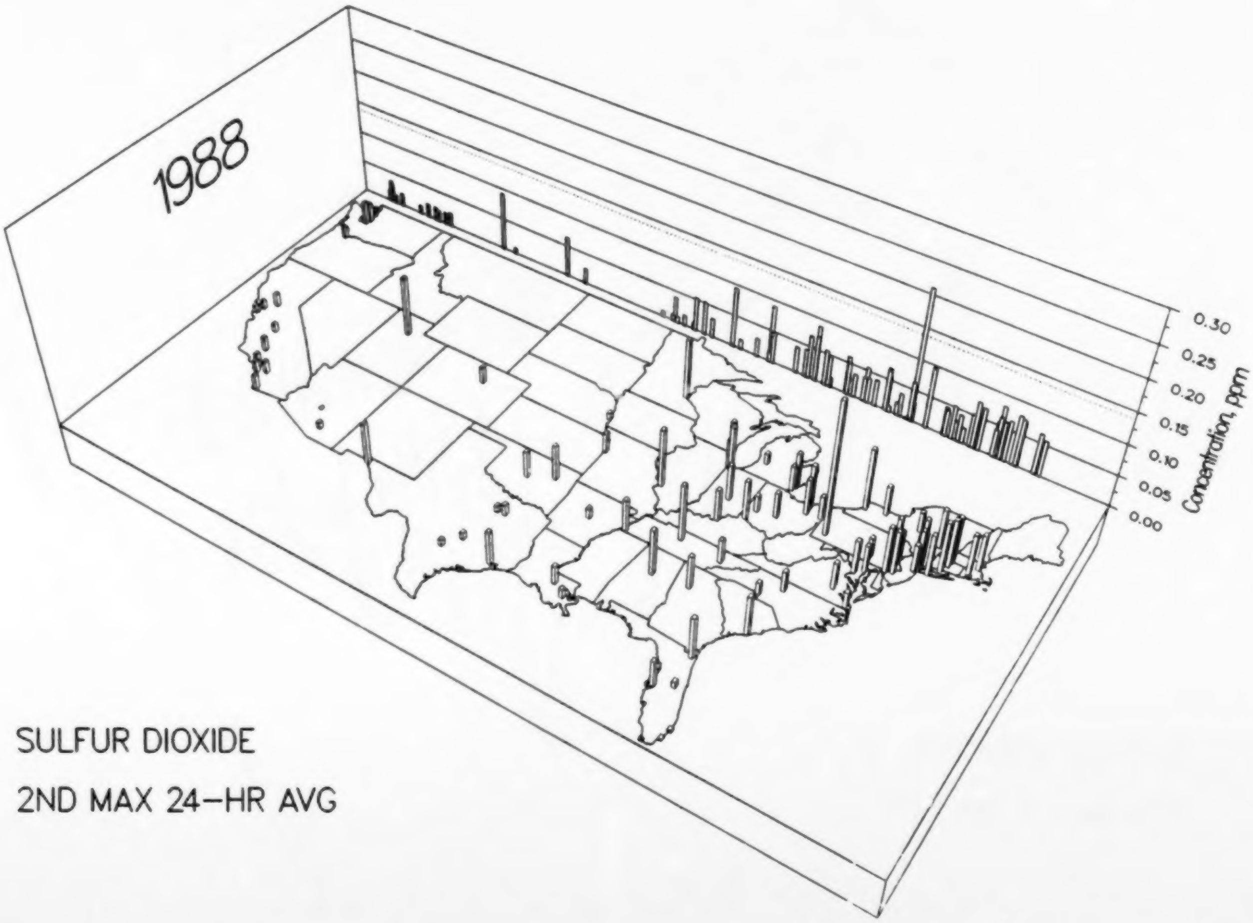

1988
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Concentration, ppm
SULFUR DIOXIDE
2ND MAX 24-HR AVG

Figure 4-6. United States map of the highest second maximum 24-hour average sulfur dioxide concentration by MSA, 1988.

The map for carbon monoxide shows the highest second highest 8-hour value recorded in 1988. Nineteen of these urban areas in all geographic regions have air quality exceeding the 9 ppm level of the standard. The highest concentration recorded in 1988 is found in Los Angeles, CA (Figure 4-7).

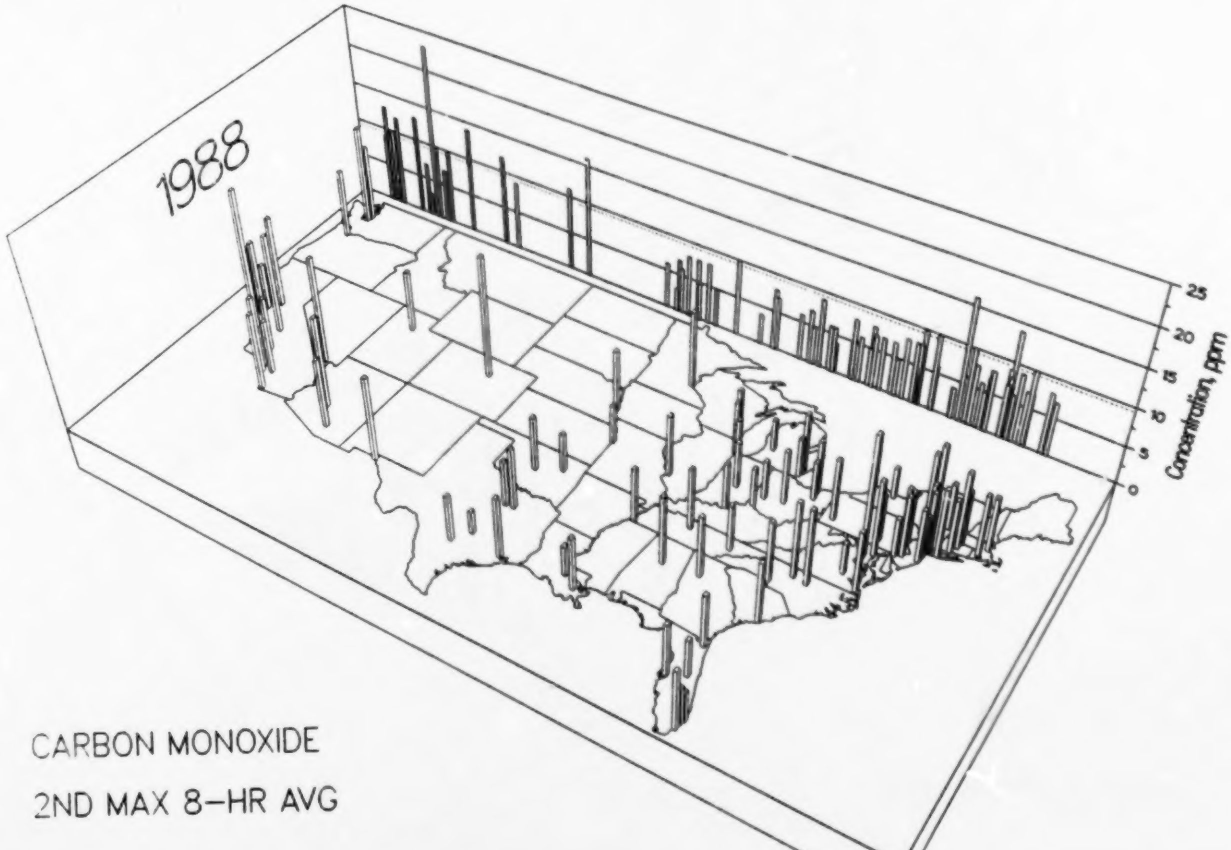

1988
25
20
15
10
5
0
Concentration, ppm
CARBON MONOXIDE
2ND MAX 8-HR AVG

Figure 4-7. United States map of the highest second maximum nonoverlapping 8-hour average carbon monoxide concentration by MSA, 1988.

The map for nitrogen dioxide displays the maximum annual mean measured in the nation's largest metropolitan areas during 1988. Los Angeles, California, with an annual NO_2 mean of 0.061 ppm is the only area in the country exceeding the NO_2 air quality standard of 0.053 ppm (Figure 4-8).

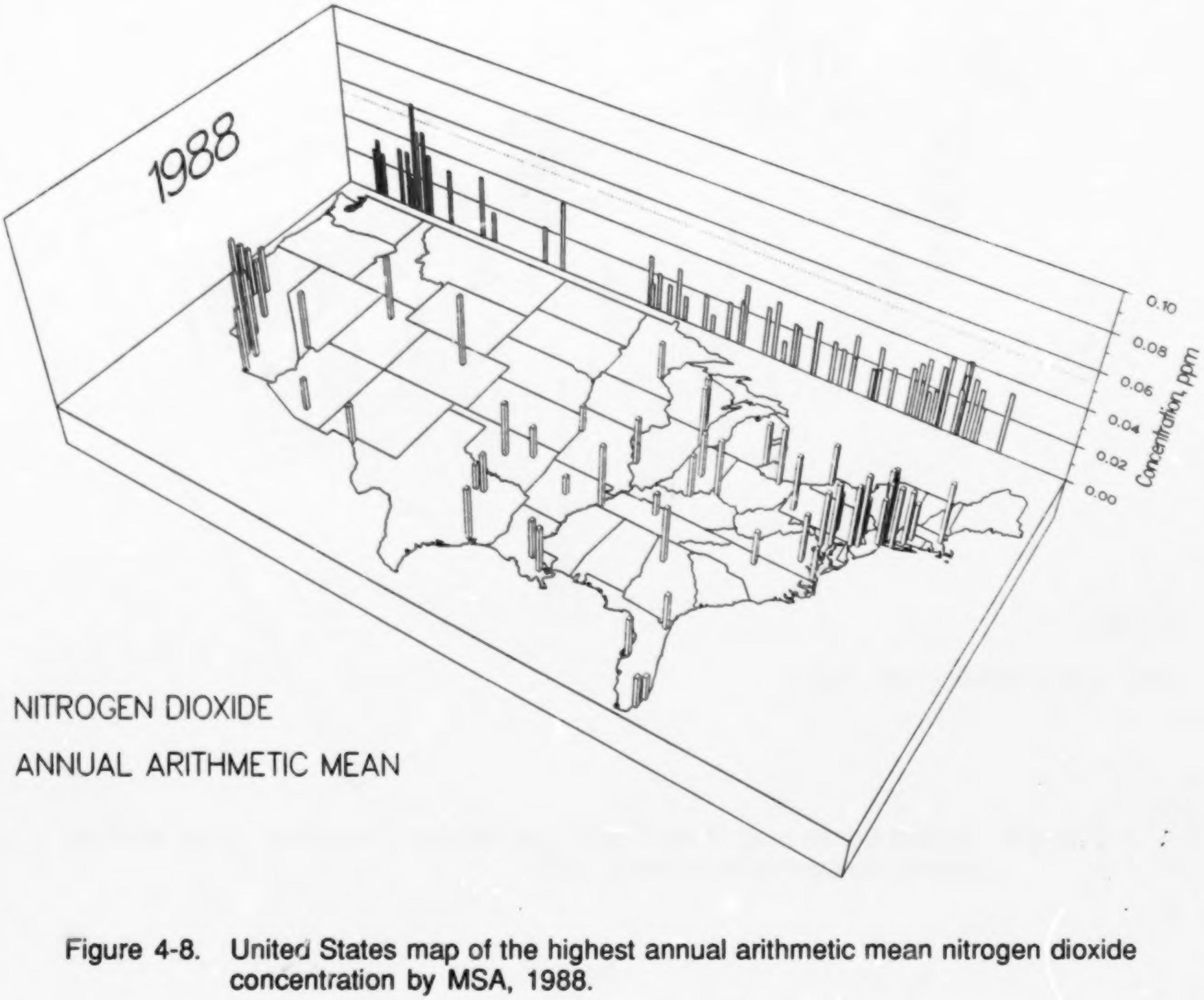


Figure 4-8. United States map of the highest annual arithmetic mean nitrogen dioxide concentration by MSA, 1988.

The ozone map shows the second highest daily maximum 1-hour concentration in the 90 largest metropolitan areas in the Continental U.S. As shown, 65 of these areas did not meet the 0.12 ppm standard in 1988. The highest concentrations are observed in Southern California, but high levels also persist in the Texas Gulf Coast, Northeast Corridor, and other heavily populated regions (Figure 4-9).

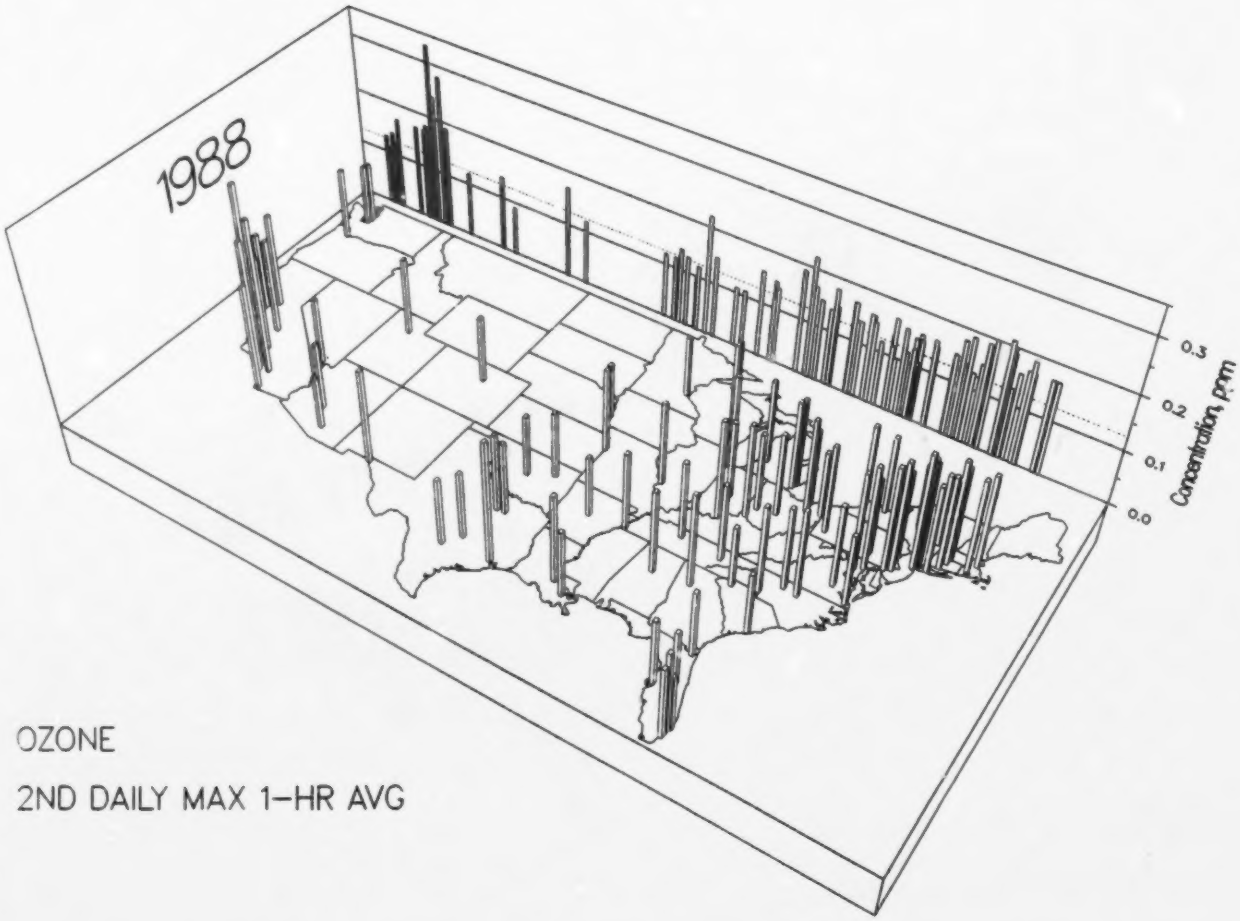

1988
0.3
0.2
0.1
0.0
Concentration, ppm
OZONE
2ND DAILY MAX 1-HR AVG

Figure 4-9. United States map of the highest second daily maximum 1-hour average ozone concentration by MSA, 1988.

The map for Pb displays maximum quarterly average concentrations in the nation's largest metropolitan areas. Exceedances of the Pb NAAQS are found in the vicinity of nonferrous smelters or other point sources of lead. The highest concentration is found at a site near a primary lead smelter in Herculaneum, MO (St. Louis MSA). Because of the switch to unleaded gasoline, areas primarily affected by automotive lead emissions show levels below the current standard of 1.5 ug/m_3 (Figure 4-10).

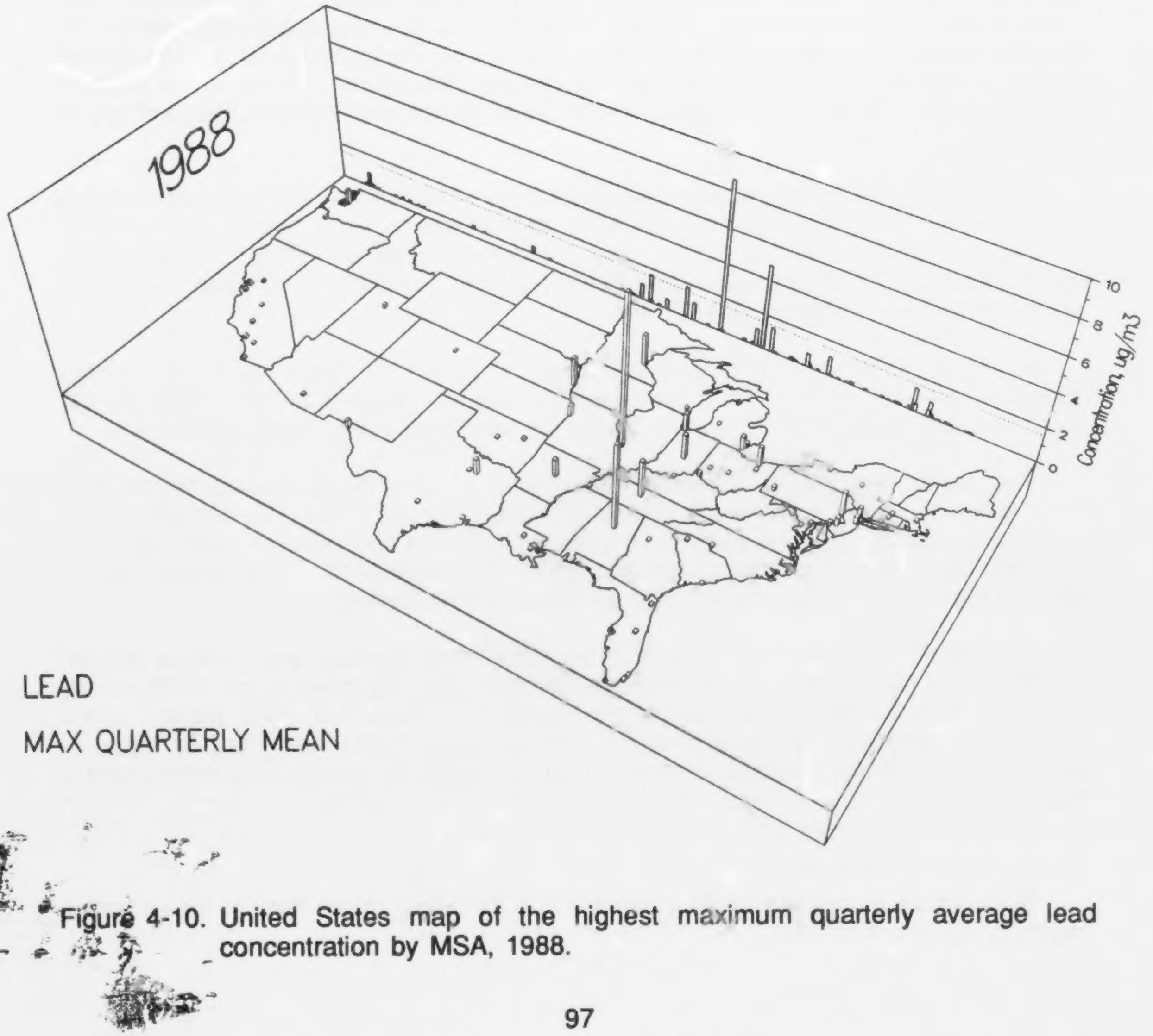


Figure 4-10. United States map of the highest maximum quarterly average lead concentration by MSA, 1988.

4.3.2 Metropolitan Statistical Area Air Quality Summary, 1988

Table 4-3 presents a summary of 1988 air quality for each Metropolitan Statistical Area (MSA) in the United States. The air quality levels reported for each metropolitan area are the highest levels measured from all available sites within the MSA. The MSAs are listed alphabetically, with the 1987 population estimate and air quality statistics for each pollutant.[1]

In the case of O_3, the problem is pervasive, and the high values associated with the pollutant can reflect a large part of the MSA. However in many cases, peak ozone concentrations occur downwind of major urban areas, e.g., peak ozone levels attributed to the Chicago metropolitan area are recorded in and near Racine, Wisconsin. In contrast, high CO values generally are highly localized and reflect areas with heavy traffic. The scale of measurement for the pollutants - PM_{10}, SO_2 and NO_2 - falls somewhere in between. Finally, while Pb measurements generally reflect Pb concentrations near roadways in the MSA, if a monitor is located near a point source of lead emissions it can produce readings substantially higher. Such is the case in several MSAs. Pb monitors located near a point source are footnoted accordingly in Table 4-3.

The pollutant-specific statistics reported in this Section are summarized in Table 4-1, with their associated primary NAAQS concentrations for a single year of data. For example, if an MSA has three ozone monitors in 1988 with second highest daily hourly maxima of 0.15 ppm, 0.14 ppm and 0.12 ppm, the highest of these, 0.15 ppm, would be reported for that MSA for 1988.

In the case of Pb, the quarterly average is based on either up to 90 24-hour measurements or one or more chemical composite measurements.[a] Most of the maximum quarterly Pb averages are based on multiple 24-hour measurements.

The same annual data completeness criteria used in the air quality trends data base was used here for the calculation of annual means. (i.e., 50 percent of the required samples). If some data have been collected at one or more sites, but none of these sites meet the annual data completeness criteria, then the reader will be advised that there are insufficient data to calculate the annual mean.

In contrast to the trends analyses in Sections 3 and 5 which used a more relaxed indicator, only maximum quarterly average Pb concentrations meeting the AIRS validity criteria of 12 observations per quarter are displayed in Table 4-3. With respect to the summary statistics on air quality levels with averaging times less than or equal to 24-hours, all sites are included, even if they do not meet the annual data completeness requirement.

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[a] A chemical composite measurement can be either a measurement for an entire month or an entire quarter.

This summary provides the reader with information on how air quality varied among the nation's metropolitan areas in 1988. The highest air quality levels measured in each MSA are summarized for each pollutant monitored in 1988. Individual MSAs are listed to provide more extensive spatial coverage for large metropolitan complexes.

The reader is cautioned that this summary is not adequate in itself to rank or to compare the MSAs according to their air quality. To rank properly the air pollution severity in different MSAs, data on population characteristics, daily population mobility, transportation patterns, industrial composition, emission inventories, meteorological factors and, most important, the spatial representativeness of the monitoring sites would also be needed.

TABLE 4-3. 1988 METROPOLITAN STATISTICAL AREA AIR QUALITY FACTBOOK
PEAK STATISTICS FOR SELECTED POLLUTANTS BY MSA

METROPOLITAN STATISTICAL AREA	1987 POPULATION	PM10 AM (UGM)	SO2 AM (PPM)	SO2 24-HR (PPM)	CO 8HR (PPM)	NO2 AM (PPM)	OZONE 2ND DMX (PPM)	PB QMAX (UGM)
ABILENE, TX	123,000	ND	ND	ND	ND	ND	ND	ND
AGUADILLA, PR	156,000	ND	ND	ND	ND	ND	ND	ND
AKRON, OH	647,000	38	0.015	0.056	5	ND	**0.17**	0.07
ALBANY, GA	117,000	ND	ND	ND	ND	ND	ND	ND
ALBANY-SCHENECTADY-TROY, NY	846,000	30	0.015	0.061	6	ND	**0.13**	0.05
ALBUQUERQUE, NM	486,000	43	ND	ND	**11**	0.018	0.11	0.04
ALEXANDRIA, LA	140,000	ND	ND	ND	ND	ND	ND	ND
ALLENTOWN-BETHLEHEM, PA-NJ	666,000	31	0.012	0.048	7	0.020	**0.16**	1.30
ALTOONA, PA	132,000	31	0.011	0.051	ND	ND	**0.14**	ND
AMARILLO, TX	197,000	IN	ND	ND	ND	ND	ND	ND
ANAHEIM-SANTA ANA, CA	2,219,000	43	0.005	0.018	**10**	0.046	**0.24**	ND
ANCHORAGE, AK	223,000	27	ND	ND	**12**	ND	ND	0.03
ANDERSON, IN	133,000	ND	ND	ND	ND	ND	ND	ND
ANDERSON, SC	141,000	ND	ND	ND	ND	ND	**0.13**	ND
ANN ARBOR, MI	268,000	ND	ND	ND	ND	ND	**0.13**	0.02
ANNISTON, AL	122,000	ND	ND	ND	ND	ND	ND	ND
APPLETON-OSHKOSH-NEENAH, WI	309,000	ND	ND	ND	ND	ND	0.11	ND
ARECIBO, PR	170,000	ND	ND	ND	ND	ND	ND	ND
ASHEVILLE, NC	171,000	29	ND	ND	ND	ND	0.11	ND
ATHENS, GA	142,000	ND	ND	ND	ND	ND	ND	ND
ATLANTA, GA	2,657,000	46	0.009	0.052	8	0.030	**0.17**	0.05
ATLANTIC CITY, NJ	303,000	IN	0.006	0.025	ND	ND	**0.15**	0.04
AUGUSTA, GA-SC	392,000	27	0.003	0.015	ND	ND	ND	0.00
AURORA-ELGIN, IL	352,000	ND	ND	ND	ND	ND	0.11	0.02
AUSTIN, TX	738,000	25	0.003	0.011	3	IN	0.12	ND
BAKERSFIELD, CA	505,000	**61**	0.006	0.021	7	0.032	**0.17**	0.13
BALTIMORE, MD	2,303,000	43	0.013	0.043	**10**	0.034	**0.19**	0.11
BANGOR, ME	84,000	31	ND	ND	ND	ND	ND	0.05
BATON ROUGE, LA	538,000	28	0.007	0.029	4	0.021	**0.16**	0.10
BATTLE CREEK, MI	138,000	37	ND	ND	ND	ND	ND	ND
BEAUMONT-PORT ARTHUR, TX	371,000	ND	0.009	0.047	3	IN	**0.16**	0.03
BEAVER COUNTY, PA	191,000	ND	0.014	0.057	3	0.020	**0.13**	0.21
BELLINGHAM, WA	115,000	30	0.005	0.026	8	ND	ND	ND
BENTON HARBOR, MI	165,000	ND	ND	ND	ND	ND	ND	ND
BERGEN-PASSAIC, NJ	1,294,000	46	0.013	0.058	7	0.036	**0.19**	0.09
BILLINGS, MT	118,000	ND	0.021	0.118	7	ND	0.08	ND
BILOXI-GULFPORT, MS	206,000	ND	0.006	0.040	ND	ND	ND	ND
BINGHAMTON, NY	260,000	ND	ND	ND	ND	ND	ND	ND
BIRMINGHAM, AL	917,000	47	IN	0.072	9	ND	**0.15**	**4.81***

BISMARK, ND	86,000	ND	ND	ND	ND	ND	ND	ND
BLOOMINGTON, IN	104,000	ND	ND	ND	ND	ND	ND	ND
BLOOMINGTON-NORMAL, IL	124,000	ND	ND	ND	ND	ND	ND	ND
BOISE CITY, ID	196,000	46	ND	ND	8	ND	ND	0.10
BOSTON, MA	2,842,000	38	0.018	0.057	7	0.033	**0.17**	0.07
BOULDER-LONGMONT, CO	217,000	35	ND	ND	6	ND	0.12	ND
BRADENTON, FL	184,000	ND	ND	ND	ND	ND	ND	ND
BRAZORIA, TX	187,000	ND	ND	ND	ND	ND	**0.14**	ND
BREMERTON, WA	174,000	ND	ND	ND	9	ND	ND	ND
BRIDGEPORT-MILFORD, CT	444,000	31	0.014	0.064	7	0.027	**0.22**	0.09
BRISTOL, CT	78,000	18	ND	ND	ND	ND	ND	0.05
BROCKTON, MA	185,000	ND	ND	ND	ND	ND	**0.13**	ND
BROWNSVILLE-HARLINGEN, TX	264,000	ND	ND	ND	ND	ND	ND	ND
BRYAN-COLLEGE STATION, TX	118,000	ND	ND	ND	ND	ND	ND	ND
BUFFALO, NY	958,000	36	0.015	0.097	6	0.022	**0.15**	0.08
BURLINGTON, NC	105,000	ND	ND	ND	ND	ND	ND	ND
BURLINGTON, VT	127,000	23	0.007	0.027	4	0.019	0.10	ND
CAGUAS, PR	275,000	ND	ND	ND	ND	ND	ND	ND
CANTON, OH	397,000	35	0.011	0.039	3	ND	**0.15**	ND
CASPER, WY	67,000	ND	ND	ND	ND	ND	ND	ND
CEDAR RAPIDS, IA	170,000	35	0.008	0.066	4	ND	0.09	ND
CHAMPAIGN-URBANA-RANTOUL, IL	173,000	ND	0.005	0.024	ND	ND	0.10	ND
CHARLESTON, SC	502,000	34	0.005	0.063	8	ND	0.11	0.03
CHARLESTON, WV	261,000	37	0.017	0.064	3	0.024	**0.16**	0.04
CHARLOTTE-GASTONIA-ROCK HILL, NC-SC	1,091,000	36	0.003	0.020	8	ND	**0.16**	0.07
CHARLOTTESVILLE, VA	123,000	40	ND	ND	ND	ND	ND	ND
CHATTANOOGA, TN-GA	432,000	42	ND	ND	ND	ND	**0.13**	ND
CHEYENNE, WY	76,000	19	ND	ND	ND	ND	ND	ND

PM10 = HIGHEST PARTICULATE (PM10) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 50 ug/m3)
SO2 = HIGHEST SULFUR DIOXIDE (SO2) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 0.03 ppm)
HIGHEST SULFUR DIOXIDE (SO2) SECOND MAXIMUM 24-HOUR CONCENTRATION (Applicable NAAQS is 0.14 ppm)
CO = HIGHEST CARBON MONOXIDE (CO) SECOND MAXIMUM NONOVERLAPPING 8-HOUR CONCENTRATION (Applicable NAAQS is 9 ppm)
NO2 = HIGHEST NITROGEN DIOXIDE (NO2) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 0.053 ppm)
O3 = HIGHEST OZONE (O3) SECOND DAILY MAXIMUM 1-HOUR CONCENTRATION (Applicable NAAQS is 0.12 ppm)
PB = HIGHEST LEAD (PB) QUARTERLY MAXIMUM CONCENTRATION (Applicable NAAQS is 1.5 ug/m3)

ND = INDICATES DATA NOT AVAILABLE
IN = INDICATES INSUFFICIENT DATA TO CALCULATE SUMMARY STATISTIC

UGM = UNITS ARE MICROGRAMS PER CUBIC METER
PPM = UNITS ARE PARTS PER MILLION

* - Impact from an industrial source in Leeds, AL. Highest population oriented site in Birmingham, AL is 0.23 ug/m3.

TABLE 4-3. 1988 METROPOLITAN STATISTICAL AREA AIR QUALITY FACTBOOK
PEAK STATISTICS FOR SELECTED POLLUTANTS BY MSA

METROPOLITAN STATISTICAL AREA	1987 POPULATION	PM10 AM (UGM)	SO2 AM (PPM)	SO2 24-HR (PPM)	CO 8HR (PPM)	NO2 AM (PPM)	OZONE 2ND DMX (PPM)	PB QMAX (UGM)
CHICAGO, IL	6,199,000	47	0.012	0.044	7	0.032	**0.22**	0.14
CHICO, CA	169,000	44	ND	ND	**10**	0.016	0.10	ND
CINCINNATI, OH-KY-IN	1,438,000	45	0.018	0.061	5	0.030	**0.17**	0.18
CLARKSVILLE-HOPKINSVILLE, TN-KY	157,000	ND	0.010	0.066	ND	ND	ND	ND
CLEVELAND, OH	1,851,000	**57**	0.017	0.069	7	0.031	**0.14**	1.09
COLORADO SPRINGS, CO	390,000	35	ND	ND	**12**	ND	0.09	0.01
COLUMBIA, MO	107,000	31	0.009	0.068	ND	ND	ND	ND
COLUMBIA, SC	451,000	34	0.003	0.017	7	ND	**0.13**	0.05
COLUMBUS, GA-AL	246,000	ND	ND	ND	ND	ND	0.10	ND
COLUMBUS, OH	1,320,000	35	0.008	0.040	7	IN	**0.15**	0.09
CORPUS CHRISTI, TX	360,000	29	0.003	0.029	ND	ND	0.11	ND
CUMBERLAND, MD-WV	102,000	ND	0.013	0.055	5	ND	ND	ND
DALLAS, TX	2,456,000	39	0.005	0.017	8	0.021	**0.13**	0.87*
DANBURY, CT	189,000	26	0.009	0.051	ND	ND	**0.20**	0.05
DANVILLE, VA	109,000	ND	ND	ND	ND	ND	ND	ND
DAVENPORT-ROCK ISLAND-MOLINE, IA-IL	367,000	34	0.004	0.024	4	ND	0.11	0.17
DAYTON-SPRINGFIELD, OH	939,000	33	0.006	0.026	5	ND	**0.14**	0.09
DAYTONA BEACH, FL	332,000	ND	0.002	0.008	ND	ND	ND	ND
DECATUR, AL	131,000	ND	ND	ND	ND	ND	ND	ND
DECATUR, IL	125,000	40	0.015	**0.162**	ND	ND	0.11	0.10
DENVER, CO	1,645,000	45	0.008	0.025	**16**	0.039	0.12	0.08
DES MOINES, IA	385,000	40	ND	ND	5	ND	0.06	ND
DETROIT, MI	4,362,000	**52**	0.015	0.056	8	0.023	**0.16**	0.24
DOTHAN, AL	130,000	ND	ND	ND	ND	ND	ND	ND
DUBUQUE, IA	91,000	ND	0.005	0.052	7	ND	ND	ND
DULUTH, MN-WI	242,000	28	0.016	**0.156**	5	ND	ND	0.04
EAU CLAIRE, WI	137,000	ND	ND	ND	ND	ND	ND	ND
EL PASO, TX	573,000	**62**	0.017	0.065	**11**	0.021	**0.17**	0.41
ELKHART-GOSHEN, IN	150,000	ND	ND	ND	ND	ND	ND	ND
ELMIRA, NY	90,000	ND	0.007	0.027	ND	ND	0.12	ND
ENID, OK	60,000	ND	ND	ND	ND	ND	ND	ND
ERIE, PA	279,000	35	0.014	0.050	5	0.016	**0.15**	ND
EUGENE-SPRINGFIELD, OR	265,000	**52**	ND	ND	7	ND	0.12	0.03
EVANSVILLE, IN-KY	281,000	41	0.020	0.136	3	0.022	**0.13**	ND
FALL RIVER, MA-RI	153,000	ND	0.010	0.040	ND	ND	ND	ND
FARGO-MOORHEAD, ND-MN	147,000	ND	ND	ND	ND	ND	ND	ND
FAYETTEVILLE, NC	259,000	33	ND	ND	7	ND	**0.13**	ND
FAYETTEVILLE-SPRINGDALE, AR	110,000	ND	ND	ND	ND	ND	ND	ND
FITCHBURG-LEOMINSTER, MA	96,000	ND	ND	ND	ND	ND	ND	ND
FLINT, MI	435,000	25	0.005	0.016	ND	ND	**0.13**	0.02

FLORENCE, AL	136,000	ND	0.007	0.049	ND	ND	ND	ND
FLORENCE, SC	117,000	ND	ND	ND	ND	ND	ND	0.04
FORT COLLINS, CO	180,000	28	ND	ND	**11**	ND	0.10	ND
FORT LAUDERDALE-HOLLYWOOD-POMPANO, FL	1,163,000	22	ND	ND	5	ND	**0.15**	0.04
FORT MYERS-CAPE CORAL, FL	295,000	ND	ND	ND	ND	ND	0.06	ND
FORT PIERCE, FL	215,000	ND	ND	ND	ND	ND	ND	ND
FORT SMITH, AR-OK	178,000	ND	ND	ND	ND	ND	ND	ND
FORT WALTON BEACH, FL	145,000	ND	ND	ND	ND	ND	ND	ND
FORT WAYNE, IN	364,000	IN	0.005	0.019	7	0.010	**0.13**	ND
FORT WORTH-ARLINGTON, TX	1,269,000	26	0.002	0.010	6	0.014	**0.14**	0.05
FRESNO, CA	597,000	**60**	0.003	0.013	**13**	0.032	**0.17**	0.07
GADSDEN, AL	103,000	37	ND	ND	ND	ND	ND	ND
GAINESVILLE, FL	205,000	ND	ND	ND	ND	ND	ND	ND
GALVESTON-TEXAS CITY, TX	211,000	25	ND	ND	ND	ND	ND	0.04
GARY-HAMMOND, IN	604,000	49	0.014	0.069	5	ND	**0.17**	1.00+
GLENS FALLS, NY	112,000	ND	0.005	0.040	ND	ND	ND	ND
GRAND FORKS, ND	70,000	ND	ND	ND	ND	ND	ND	ND
GRAND RAPIDS, MI	657,000	25	0.003	0.016	4	ND	**0.15**	0.05
GREAT FALLS, MT	78,000	IN	ND	ND	9	ND	ND	ND
GREELEY, CO	135,000	39	ND	ND	9	ND	0.10	ND
GREEN BAY, WI	188,000	23	0.009	0.040	ND	ND	0.10	ND
GREENSBORO-WINSTON SALEM-HIGH POINT, NC	916,000	38	0.008	0.032	**10**	0.018	**0.15**	ND
GREENVILLE-SPARTANBURG, SC	612,000	38	ND	ND	ND	ND	0.11	0.08
HAGERSTOWN, MD	116,000	ND	ND	ND	ND	ND	ND	ND
HAMILTON-MIDDLETOWN, OH	276,000	42	0.011	0.048	ND	ND	**0.14**	ND
HARRISBURG-LEBANON-CARLISLE, PA	584,000	34	0.009	0.031	6	0.021	**0.14**	ND
HARTFORD, CT	748,000	30	0.011	0.076	**10**	0.020	**0.19**	0.07

PM10 = HIGHEST PARTICULATE (PM10) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 50 ug/m3)
SO2 = HIGHEST SULFUR DIOXIDE (SO2) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 0.03 ppm)
HIGHEST SULFUR DIOXIDE (SO2) SECOND MAXIMUM 24-HOUR CONCENTRATION (Applicable NAAQS is 0.14 ppm)
CO = HIGHEST CARBON MONOXIDE (CO) SECOND MAXIMUM NONOVERLAPPING 8-HOUR CONCENTRATION (Applicable NAAQS is 9 ppm)
NO2 = HIGHEST NITROGEN DIOXIDE (NO2) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 0.053 ppm)
O3 = HIGHEST OZONE (O3) SECOND DAILY MAXIMUM 1-HOUR CONCENTRATION (Applicable NAAQS is 0.12 ppm)
PB = HIGHEST LEAD (PB) QUARTERLY MAXIMUM CONCENTRATION (Applicable NAAQS is 1.5 ug/m3)

ND = INDICATES DATA NOT AVAILABLE
IN = INDICATES INSUFFICIENT DATA TO CALCULATE SUMMARY STATISTIC

UGM = UNITS ARE MICROGRAMS PER CUBIC METER
PPM = UNITS ARE PARTS PER MILLION

* - Impact from an industrial source in Collin County, TX. Highest site in Dallas, TX is 0.47 ug/m3.

+ - Impact from an industrial source in Hammond, In.

TABLE 4-3. 1988 METROPOLITAN STATISTICAL AREA AIR QUALITY FACTBOOK
PEAK STATISTICS FOR SELECTED POLLUTANTS BY MSA

METROPOLITAN STATISTICAL AREA	1987 POPULATION	PM10 AM (UGM)	[illegible]2 AM (PPM)	SO2 24-HR (PPM)	CO 8HR (PPM)	NO2 AM (PPM)	OZONE 2ND DMX (PPM)	PB QMAX (UGM)
HICKORY, NC	219,000	ND	ND	ND	ND	ND	0.09	ND
HONOLULU, HI	831,000	24	0.001	0.003	4	ND	0.03	0.01
HOUMA-THIBODAUX, LA	185,000	ND	ND	ND	ND	ND	ND	ND
HOUSTON, TX	3,228,000	32	0.008	0.053	8	0.028	**0.22**	0.09
HUNTINGTON-ASHLAND, WV-KY-OH	323,000	43	0.011	0.060	4	0.016	**0.17**	0.21
HUNTSVILLE, AL	231,000	38	ND	ND	5	ND	**0.13**	ND
INDIANAPOLIS, IN	1,229,000	41	0.014	0.056	6	0.024	**0.14**	1.39*
IOWA CITY, IA	86,000	ND	ND	ND	ND	ND	0.09	ND
JACKSON, MI	147,000	ND	ND	ND	ND	ND	ND	ND
JACKSON, MS	396,000	30	ND	ND	5	ND	0.10	0.08
JACKSON, TN	78,000	33	ND	ND	ND	ND	ND	ND
JACKSONVILLE, FL	878,000	31	0.008	0.066	7	0.019	0.12	0.07
JACKSONVILLE, NC	126,000	ND	ND	ND	ND	ND	ND	ND
JANESVILLE-BELOIT, WI	135,000	ND	IN	0.017	ND	IN	0.11	ND
JERSEY CITY, NJ	547,000	36	0.017	0.065	8	0.033	**0.20**	0.10
JOHNSON CITY-KINGSPORT-BRISTOL, TN-VA	443,000	37	0.012	0.058	4	IN	0.12	ND
JOHNSTOWN, PA	252,000	ND	0.017	0.055	4	0.019	**0.14**	0.30
JOLIET, IL	377,000	34	ND	ND	ND	ND	0.12	0.02
JOPLIN, MO	134,000	ND	ND	ND	ND	ND	ND	ND
KALAMAZOO, MI	219,000	ND	ND	ND	ND	ND	ND	0.03
KANKAKEE, IL	98,000	ND	ND	ND	ND	ND	ND	ND
KANSAS CITY, MO-KS	1,546,000	45	0.008	0.031	5	0.014	**0.15**	0.57
KENOSHA, WI	120,000	ND	0.005	0.019	ND	0.014	**0.19**	ND
KILLEN-TEMPLE, TX	234,000	ND	ND	ND	ND	ND	ND	ND
KNOXVILLE, TN	594,000	42	0.014	0.037	6	ND	**0.14**	ND
KOKOMO, IN	101,000	ND	ND	ND	ND	ND	ND	ND
LA CROSSE, WI	95,000	ND	ND	ND	ND	ND	ND	ND
LAFAYETTE, LA	212,000	ND	ND	ND	ND	ND	0.11	ND
LAFAYETTE, IN	125,000	37	0.005	0.025	1	ND	**0.13**	0.03
LAKE CHARLES, LA	172,000	ND	0.003	0.010	ND	ND	**0.13**	ND
LAKE COUNTY, IL	494,000	ND	ND	ND	ND	ND	**0.16**	ND
LAKELAND-WINTER HAVEN, FL	387,000	ND	0.004	0.019	ND	ND	ND	ND
LANCASTER, PA	404,000	ND	0.007	0.028	3	0.020	**0.13**	0.07
LANSING-EAST LANSING, MI	428,000	24	0.006	0.019	ND	ND	0.12	0.03
LAREDO, TX	124,000	IN	ND	ND	ND	ND	ND	ND
LAS CRUCES, NM	129,000	39	0.003	0.050	7	ND	0.11	0.20
LAS VEGAS, NV	600,000	**63**	ND	ND	**14**	0.031	0.12	ND
LAWRENCE, KS	75,000	ND	ND	ND	ND	ND	ND	ND
LAWRENCE-HAVERHILL, MA-NH	375,000	ND	0.010	0.041	ND	ND	**0.16**	ND
LAWTON, OK	119,000	32	0.006	0.013	ND	ND	ND	ND

LEWISTON-AUBURN, ME	85,000	ND	0.007	0.044	ND	ND	0.12	0.07
LEXINGTON-FAYETTE, KY	342,000	ND	0.007	0.027	5	0.018	**0.13**	ND
LIMA, OH	156,000	ND	0.006	0.024	ND	ND	0.11	0.42
LINCOLN, NE	208,000	ND	ND	ND	9	ND	0.08	ND
LITTLE ROCK-NORTH LITTLE ROCK, AR	512,000	35	0.002	0.016	ND	0.010	0.11	0.99
LONGVIEW-MARSHALL, TX	167,000	ND	ND	ND	ND	ND	0.12	ND
LORAIN-ELYRIA, OH	268,000	IN	0.011	0.040	ND	ND	0.12	ND
LOS ANGELES-LONG BEACH, CA	8,505,000	**65**	0.007	0.021	**23**	**0.061**	**0.33**	0.15
LOUISVILLE, KY-IN	967,000	45	0.010	0.050	6	0.023	**0.18**	0.09
LOWELL, MA-NH	260,000	ND	ND	ND	6	ND	ND	0.05
LUBBOCK, TX	228,000	39	ND	ND	ND	ND	ND	ND
LYNCHBURG, VA	143,000	31	ND	ND	ND	ND	ND	ND
MACON-WARNER ROBINS, GA	283,000	ND	0.004	0.016	ND	ND	ND	ND
MADISON, WI	347,000	ND	0.005	0.019	4	ND	0.10	ND
MANCHESTER, NH	146,000	27	0.009	0.049	9	0.024	**0.14**	0.04
MANSFIELD, OH	128,000	ND	IN	0.024	ND	ND	ND	ND
MAYAGUEZ, PR	210,000	ND	ND	ND	ND	ND	ND	ND
MCALLEN-EDINBURG-MISSION, TX	379,000	ND	ND	ND	ND	ND	ND	ND
MEDFORD, OR	143,000	**72**	ND	ND	**11**	ND	0.11	0.05
MELBOURNE-TITUSVILLE-PALM BAY, FL	375,000	ND	ND	ND	ND	ND	0.07	ND
MEMPHIS, TN-AR-MS	972,000	28	0.008	0.051	7	0.034	**0.14**	0.13
MERCED, CA	166,000	47	ND	ND	ND	ND	ND	ND
MIAMI-HIALEAH, FL	1,791,000	30	0.001	0.002	8	0.017	**0.13**	0.09
MIDDLESEX-SOMERSET-HUNTERDON, NJ	966,000	IN	0.012	0.043	5	0.025	**0.21**	0.38
MIDDLETOWN, CT	85,000	IN	ND	ND	ND	ND	**0.18**	0.03
MIDLAND, TX	108,000	ND	ND	ND	ND	ND	ND	ND
MILWAUKEE, WI	1,389,000	36	0.006	0.042	6	0.027	**0.19**	0.13

PM10 = HIGHEST PARTICULATE (PM10) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 50 ug/m3)
SO2 = HIGHEST SULFUR DIOXIDE (SO2) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 0.03 ppm)
HIGHEST SULFUR DIOXIDE (SO2) SECOND MAXIMUM 24-HOUR CONCENTRATION (Applicable NAAQS is 0.14 ppm)
CO = HIGHEST CARBON MONOXIDE (CO) SECOND MAXIMUM NONOVERLAPPING 8-HOUR CONCENTRATION (Applicable NAAQS is 9 ppm)
NO2 = HIGHEST NITROGEN DIOXIDE (NO2) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 0.053 ppm)
O3 = HIGHEST OZONE (O3) SECOND DAILY MAXIMUM 1-HOUR CONCENTRATION (Applicable NAAQS is 0.12 ppm)
PB = HIGHEST LEAD (PB) QUARTERLY MAXIMUM CONCENTRATION (Applicable NAAQS is 1.5 ug/m3)

ND = INDICATES DATA NOT AVAILABLE
IN = INDICATES INSUFFICIENT DATA TO CALCULATE SUMMARY STATISTIC

UGM = UNITS ARE MICROGRAMS PER CUBIC METER
PPM = UNITS ARE PARTS PER MILLION

* - Impact from an industrial source in Indianapolis, IN.

TABLE 4-3. 1988 METROPOLITAN STATISTICAL AREA AIR QUALITY FACTBOOK
PEAK STATISTICS FOR SELECTED POLLUTANTS BY MSA

METROPOLITAN STATISTICAL AREA	1987 POPULATION	PM10 AM (UGM)	SO2 AM (PPM)	SO2 24-HR (PPM)	CO 8HR (PPM)	NO2 AM (PPM)	OZONE 2ND DMX (PPM)	PB QMAX (UGM)
MINNEAPOLIS-ST. PAUL, MN-WI	2,336,000	38	0.013	0.095	**10**	0.020	0.11	**1.77***
MOBILE, AL	483,000	41	0.008	0.054	ND	ND	0.11	ND
MODESTO, CA	327,000	41	0.004	0.011	**10**	0.027	**0.13**	ND
MONMOUTH-OCEAN, NJ	957,000	ND	ND	ND	7	ND	ND	ND
MONROE, LA	146,000	ND	0.005	0.024	ND	ND	0.11	ND
MONTGOMERY, AL	297,000	23	ND	ND	ND	ND	0.11	ND
MUNCIE, IN	121,000	ND	ND	ND	ND	ND	ND	ND
MUSKEGON, MI	159,000	ND	IN	0.013	2	ND	**0.15**	0.03
NAPLES, FL	128,000	ND	ND	ND	ND	ND	ND	ND
NASHUA, NH	172,000	ND	0.008	0.042	7	ND	**0.13**	0.04
NASHVILLE, TN	956,000	42	0.012	0.089	8	0.012	**0.14**	**2.04+**
NASSAU-SUFFOLK, NY	2,631,000	ND	0.011	0.065	9	0.033	**0.16**	0.07
NEW BEDFORD, MA	166,000	ND	ND	ND	ND	ND	**0.16**	ND
NEW BRITAIN, CT	147,000	IN	0.010	0.076	ND	ND	ND	0.03
NEW HAVEN-MERIDEN, CT	519,000	48	0.017	0.079	7	0.029	**0.17**	0.10
NEW LONDON-NORWICH, CT-RI	259,000	IN	0.009	0.047	ND	ND	**0.15**	0.04
NEW ORLEANS, LA	1,321,000	37	0.004	0.015	7	0.024	0.12	0.10
NEW YORK, NY	8,529,000	**56**	0.024	0.083	**14**	0.041	**0.18**	0.21
NEWARK, NJ	1,891,000	38	0.014	0.056	9	0.040	**0.18**	0.84
NIAGARA FALLS, NY	216,000	ND	0.015	0.068	4	ND	**0.14**	ND
NORFOLK-VIRGINIA BEACH-NEWPORT NEWS, VA	1,346,000	33	0.007	0.025	8	0.017	**0.13**	0.10
NORWALK, CT	126,000	IN	IN	0.055	ND	ND	ND	0.04
OAKLAND, CA	1,968,000	23	0.003	0.013	6	0.026	**0.14**	0.20
OCALA, FL	181,000	ND	ND	ND	ND	ND	ND	ND
ODESSA, TX	127,000	25	ND	ND	ND	ND	ND	ND
OKLAHOMA CITY, OK	975,000	28	0.010	0.041	7	0.029	0.11	0.10
OLYMPIA, WA	151,000	ND	ND	ND	ND	ND	ND	ND
OMAHA, NE-IA	616,000	45	0.003	0.011	8	ND	0.10	**1.63@**
ORANGE COUNTY, NY	288,000	ND	ND	ND	ND	ND	ND	1.18#
ORLANDO, FL	935,000	34	0.002	0.010	5	ND	0.10	0.06
OWENSBORO, KY	88,000	IN	0.010	0.040	6	0.015	**0.14**	0.07
OXNARD-VENTURA, CA	628,000	34	ND	ND	3	0.018	**0.18**	ND
PANAMA CITY, FL	122,000	ND	ND	ND	ND	ND	ND	ND
PARKERBURG-MARIETTA, WV-OH	156,000	ND	0.015	0.076	ND	ND	**0.17**	0.02
PASCAGOULA, MS	128,000	ND	0.006	0.013	ND	ND	0.11	ND
PAWTUCKET-WOONSOCKET-ATTLEBORO, RI-MA	322,000	31	0.013	0.054	ND	ND	ND	ND
PENSACOLA, FL	344,000	ND	0.007	0.057	ND	ND	0.10	ND
PEORIA, IL	339,000	23	0.009	0.065	8	ND	0.11	0.04
PHILADELPHIA, PA-NJ	4,866,000	47	0.016	0.068	8	0.039	**0.20**	0.44
PHOENIX, AZ	1,960,000	**57**	0.001	0.001	**12**	ND	0.12	ND

PINE BLUFF, AR	91,000	ND	ND	ND	ND	ND	ND	ND
PITTSBURGH, PA	2,105,000	**54**	0.028	**0.210**	8	0.030	**0.16**	0.20
PITTSFIELD, MA	80,000	ND	ND	ND	ND	ND	ND	ND
PONCE, PR	235,000	IN	ND	ND	ND	ND	ND	ND
PORTLAND, ME	210,000	25	0.010	0.044	5	ND	**0.17**	0.09
PORTLAND, OR-WA	1,168,000	40	0.006	0.018	9	IN	**0.13**	0.18
PORTSMOUTH-DOVER-ROCHESTER, NH-ME	215,000	23	0.006	0.034	ND	ND	0.11	0.00
POUGHKEEPSIE, NY	258,000	ND	0.014	0.061	ND	ND	**0.14**	ND
PROVIDENCE, RI	643,000	34	0.016	0.065	8	IN	**0.17**	0.07
PROVO-OREM, UT	242,000	**54**	ND	ND	**11**	0.028	0.11	ND
PUEBLO, CO	127,000	35	ND	ND	ND	ND	ND	0.04
RACINE, WI	173,000	ND	ND	ND	7	ND	**0.18**	ND
RALEIGH-DURHAM, NC	665,000	37	ND	ND	**10**	ND	**0.16**	ND
RAPID CITY, SD	80,000	37	ND	ND	ND	ND	ND	ND
READING, PA	324,000	ND	0.014	0.057	5	0.024	**0.15**	0.65
REDDING, CA	136,000	23	ND	ND	ND	0.013	0.11	ND
RENO, NV	232,000	ND	ND	ND	**10**	ND	**0.19**	ND
RICHLAND-KENNEWICK-PASCO, WA	150,000	37	ND	ND	ND	ND	ND	ND
RICHMOND-PETERSBURG, VA	825,000	30	0.009	0.042	4	0.026	**0.15**	ND
RIVERSIDE-SAN BERNARDINO, CA	2,119,000	**95**	0.003	0.019	7	0.047	**0.28**	0.09
ROANOKE, VA	224,000	35	0.004	0.018	3	0.016	**0.13**	ND
ROCHESTER, MN	98,000	32	0.003	0.016	7	ND	ND	ND
ROCHESTER, NY	979,000	34	0.014	0.046	4	ND	**0.14**	0.09
ROCKFORD, IL	281,000	17	ND	ND	8	ND	0.11	0.00
SACRAMENTO, CA	1,336,000	48	0.010	0.020	**12**	0.025	**0.17**	0.09
SAGINAW-BAY CITY-MIDLAND, MI	404,000	34	ND	ND	2	IN	ND	0.04
ST. CLOUD, MN	177,000	28	0.002	0.013	ND	ND	ND	ND
ST. JOSEPH, MO	85,000	46	0.004	0.023	ND	ND	ND	ND

PM10 = HIGHEST PARTICULATE (PM10) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 50 ug/m3)
SO2 = HIGHEST SULFUR DIOXIDE (SO2) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 0.03 ppm)
HIGHEST SULFUR DIOXIDE (SO2) SECOND MAXIMUM 24-HOUR CONCENTRATION (Applicable NAAQS is 0.14 ppm)
CO = HIGHEST CARBON MONOXIDE (CO) SECOND MAXIMUM NONOVERLAPPING 8-HOUR CONCENTRATION (Applicable NAAQS is 9 ppm)
NO2 = HIGHEST NITROGEN DIOXIDE (NO2) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 0.053 ppm)
O3 = HIGHEST OZONE (O3) SECOND DAILY MAXIMUM 1-HOUR CONCENTRATION (Applicable NAAQS is 0.12 ppm)
PB = HIGHEST LEAD (PB) QUARTERLY MAXIMUM CONCENTRATION (Applicable NAAQS is 1.5 ug/m3)

ND = INDICATES DATA NOT AVAILABLE
IN = INDICATES INSUFFICIENT DATA TO CALCULATE SUMMARY STATISTIC

UGM = UNITS ARE MICROGRAMS PER CUBIC METER
PPM = UNITS ARE PARTS PER MILLION

* - Impact from an industrial source in Eagan, MN. Highest site in Minneapolis, MN is 0.07 ug/m3.
+ - Impact from an industrial source in Williamson County, TN. Highest site in Nashville, TN is 0.13 ug/m3.
@ - Impact from an industrial source in Omaha, NE.
# - Impact from an industrial source in Orange County, NY.

TABLE 4-3. 1988 METROPOLITAN STATISTICAL AREA AIR QUALITY FACTBOOK
PEAK STATISTICS FOR SELECTED POLLUTANTS BY MSA

METROPOLITAN STATISTICAL AREA	1987 POPULATION	PM10 AM (UGM)	SO2 AM (PPM)	SO2 24-HR (PPM)	CO 8HR (PPM)	NO2 AM (PPM)	OZONE 2ND DMX (PPM)	PB QMAX (UGM)
ST. LOUIS, MO-IL	2,458,000	**69**	0.017	0.091	8	0.025	**0.15**	**8.59***
SALEM, OR	266,000	ND	ND	ND	6	ND	ND	ND
SALEM-GLOUCESTER, MA	258,000	ND	ND	ND	ND	ND	ND	ND
SALINAS-SEASIDE-MONTEREY, CA	343,000	20	ND	ND	ND	ND	0.08	ND
SALT LAKE CITY-OGDEN, UT	1,055,000	**54**	0.022	0.093	8	0.035	**0.14**	0.19
SAN ANGELO, TX	99,000	ND	ND	ND	ND	ND	ND	ND
SAN ANTONIO, TX	1,307,000	29	0.001	0.010	6	IN	0.12	0.06
SAN DIEGO, CA	2,286,000	40	0.005	0.022	**10**	0.035	**0.19**	0.09
SAN FRANCISCO, CA	1,590,000	28	0.002	0.012	9	0.026	0.10	0.16
SAN JOSE, CA	1,415,000	36	ND	ND	**10**	0.032	0.12	0.14
SAN JUAN, PR	1,541,000	45	0.003	0.027	6	ND	0.09	0.05
SANTA BARBARA-SANTA MARIA-LOMPOC, CA	341,000	34	0.002	0.015	7	0.017	0.12	0.04
SANTA CRUZ, CA	222,000	IN	0.001	0.007	1	0.008	0.08	ND
SANTA FE, NM	111,000	17	ND	ND	4	ND	ND	ND
SANTA ROSA-PETALUMA, CA	354,000	27	ND	ND	5	0.016	0.10	0.05
SARASOTA, FL	256,000	ND	0.002	0.012	ND	ND	0.10	ND
SAVANNAH, GA	241,000	ND	0.007	0.046	ND	ND	ND	ND
SCRANTON-WILKES-BARRE, PA	731,000	30	0.010	0.052	6	0.019	**0.15**	ND
SEATTLE, WA	1,796,000	40	0.008	0.029	**10**	ND	0.11	0.84
SHARON, PA	123,000	37	0.011	0.054	ND	ND	**0.14**	ND
SHEBOYGAN, WI	102,000	ND	0.003	0.021	ND	ND	**0.17**	ND
SHERMAN-DENISON, TX	100,000	ND	ND	ND	ND	ND	ND	ND
SHREVEPORT, LA	364,000	24	0.003	0.009	ND	ND	0.11	ND
SIOUX CITY, IA-NE	115,000	31	ND	ND	ND	ND	ND	ND
SIOUX FALLS, SD	124,000	22	ND	ND	ND	ND	ND	ND
SOUTH BEND-MISHAWAKA, IN	242,000	31	0.007	0.024	4	ND	**0.14**	ND
SPOKANE, WA	355,000	**63**	ND	ND	**14**	ND	ND	ND
SPRINGFIELD, IL	191,000	ND	0.007	0.074	5	ND	0.11	ND
SPRINGFIELD, MO	229,000	23	0.009	0.095	7	0.010	0.11	ND
SPRINGFIELD, MA	517,000	44	0.012	0.074	7	IN	**0.17**	0.09
STAMFORD, CT	193,000	28	0.010	0.062	7	ND	**0.22**	0.08
STATE COLLEGE, PA	115,000	ND	ND	ND	ND	ND	ND	ND
STEUBENVILLE-WEIRTON, OH-WV	149,000	47	**0.039**	0.125	**20**	0.021	0.12	0.05
STOCKTON, CA	443,000	44	0.003	0.010	8	0.026	**0.13**	0.06
SYRACUSE, NY	647,000	29	0.005	0.032	8	ND	0.12	0.06
TACOMA, WA	545,000	45	0.008	0.035	**13**	ND	0.11	0.04
TALLAHASSEE, FL	223,000	ND	ND	ND	ND	ND	0.09	ND
TAMPA-ST. PETERSBURG-CLEARWATER, FL	1,965,000	33	0.010	0.042	7	0.021	0.12	ND
TERRE HAUTE, IN	132,000	40	0.009	0.037	ND	ND	0.08	ND
TEXARKANA, TX-AR	120,000	ND	ND	ND	ND	ND	ND	ND

TOLEDO, OH	611,000	35	0.009	0.039	5	ND	**0.16**	0.76
TOPEKA, KS	162,000	IN	ND	ND	ND	ND	ND	0.02
TRENTON, NJ	327,000	32	0.009	0.044	4	ND	**0.20**	ND
TUCSON, AZ	619,000	**68**	0.003	0.010	9	0.017	0.09	0.09
TULSA, OK	733,000	45	0.010	0.054	5	0.017	0.12	0.13
TUSCALOOSA, AL	144,000	ND	ND	ND	ND	ND	ND	ND
TYLER, TX	153,000	ND	ND	ND	ND	ND	ND	ND
UTICA-ROME, NY	314,000	ND	ND	ND	ND	ND	0.12	ND
VALLEJO-FAIRFIELD-NAPA, CA	404,000	27	0.002	0.006	9	0.019	0.12	0.11
VANCOUVER, WA	216,000	ND	ND	ND	**10**	ND	ND	ND
VICTORIA, TX	75,000	ND	ND	ND	ND	ND	ND	ND
VINELAND-MILLVILE-BRIDGETON, NJ	138,000	ND	0.008	0.034	ND	ND	**0.15**	ND
VISALIA-TULARE-PORTERVILLE, CA	292,000	IN	0.002	0.008	6	0.023	**0.13**	ND
WACO, TX	189,000	ND	ND	ND	ND	ND	ND	ND
WASHINGTON, DC-MD-VA	3,646,000	35	0.015	0.053	**16**	0.030	**0.18**	0.05
WATERBURY, CT	213,000	33	0.010	0.074	ND	ND	ND	0.08
WATERLOO-CEDAR FALLS, IA	149,000	ND	ND	ND	ND	ND	ND	ND
WAUSAU, WI	111,000	ND	0.009	0.060	ND	ND	ND	ND
WEST PALM BEACH-BOCA RATON-DELRAY, FL	790,000	ND	0.001	0.004	4	0.013	0.10	ND
WHEELING, WV-OH	173,000	32	0.025	0.077	4	0.018	0.12	0.20
WICHITA, KS	475,000	32	ND	ND	8	ND	0.12	0.04
WICHITA FALLS, TX	126,000	ND	ND	ND	ND	ND	ND	ND
WILLIAMSPORT, PA	117,000	ND	0.009	0.035	ND	ND	0.12	ND
WILMINGTON, DE-NJ-MD	559,000	35	0.017	0.074	5	0.033	**0.19**	0.19
WILMINGTON, NC	116,000	29	ND	ND	ND	ND	0.09	ND
WORCESTER, MA	410,000	30	0.009	0.042	6	0.029	ND	0.06
YAKIMA, WA	183,000	44	ND	ND	9	ND	ND	ND
YORK, PA	404,000	33	0.007	0.029	4	0.023	**0.14**	ND
YOUNGSTOWN-WARREN, OH	503,000	33	0.009	0.037	ND	ND	0.12	ND
YUBA CITY, CA	116,000	32	ND	ND	ND	ND	**0.13**	ND

PM10 = HIGHEST PARTICULATE (PM10) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 50 ug/m3)
SO2 = HIGHEST SULFUR DIOXIDE (SO2) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 0.03 ppm)
HIGHEST SULFUR DIOXIDE (SO2) SECOND MAXIMUM 24-HOUR CONCENTRATION (Applicable NAAQS is 0.14 ppm)
CO = HIGHEST CARBON MONOXIDE (CO) SECOND MAXIMUM NONOVERLAPPING 8-HOUR CONCENTRATION (Applicable NAAQS is 9 ppm)
NO2 = HIGHEST NITROGEN DIOXIDE (NO2) ARITHMETIC MEAN CONCENTRATION (Applicable NAAQS is 0.053 ppm)
O3 = HIGHEST OZONE (O3) SECOND DAILY MAXIMUM 1-HOUR CONCENTRATION (Applicable NAAQS is 0.12 ppm)
PB = HIGHEST LEAD (PB) QUARTERLY MAXIMUM CONCENTRATION (Applicable NAAQS is 1.5 ug/m3)

ND = INDICATES DATA NOT AVAILABLE
IN = INDICATES INSUFFICIENT DATA TO CALCULATE SUMMARY STATISTIC

UGM = UNITS ARE MICROGRAMS PER CUBIC METER
PPM = UNITS ARE PARTS PER MILLION

* - Impact from a lead smelter in Herculaneum, MO. Highest site in St. Louis, MO is 0.33 ug/m3.

4.5 REFERENCES

1. Statistical Abstract of the United States, 1989, U. S. Department of Commerce, U. S. Bureau of the Census, Appendix II.

2. "EPA Lists Places Failing To Meet Ozone or Carbon Monoxide Standards", Press Release, U.S. Environmental Protection Agency, Washington, D.C., July 27, 1989.

5. TRENDS ANALYSES FOR FIFTEEN METROPOLITAN STATISTICAL AREAS

This chapter presents trends and analyses of ambient air quality for the period 1979 through 1988 in 15 consolidated metropolitan statistical areas (CMSA) or metropolitan statistical areas (MSA). Consolidated metropolitan statistical areas are metropolitan complexes of one million or more population which have separate component areas designated primary metropolitan statistical areas. For example, the New York-Northern New Jersey-Long Island, NY-NJ-CT CMSA contains 12 MSAs which are listed separately in Chapter 4. There are 21 metropolitan complexes designated as CMSAs, 10 of which have been selected for trends analysis. The 15 areas included in these analyses are Atlanta, GA MSA; Baltimore, MD MSA; Boston-Lawrence-Salem, MA-NH CMSA; Chicago-Gary-Lake County, IL-IN-WI CMSA; Denver-Boulder, CO CMSA; Detroit-Ann Arbor, MI CMSA; Houston-Galveston-Brazoria, TX CMSA; Los Angeles-Anaheim-Riverside, CA CMSA; New York-Northern New Jersey-Long Island, NY-NJ-CT CMSA; Philadelphia-Wilmington-Trenton, PA-NJ-DE-MD CMSA; Phoenix, AZ MSA; Portland-Vancouver, OR-WA CMSA; Seattle-Tacoma, WA CMSA; St. Louis, MO-IL MSA; and Washington, DC-MD-VA MSA. These areas have been selected because they are among the largest cities in each of the EPA Regions.

Where sufficient data were available, 10-year trends in these areas are presented for the NAAQS pollutants TSP, SO_2, CO, NO_2, O_3, and Pb. If data for the 10-year trends were not available, then 5-year trends are shown where sufficient data were available. Also, the CMSA/MSA areas are grouped into seven broad geographic regions: Northeast, Midatlantic, Midwest, South, Rocky Mountain, South Coast, and Northwest, and composite averages calculated for each pollutant are presented and are compared to the national averages.

The air quality data used for the trend statistics in this chapter have been obtained from the EPA Aerometric Information Retrieval System (AIRS). This section employs the same data completeness and historical continuity criteria as the 10-year trends analyses in Chapter 3. That is, only those monitoring sites meeting the historical continuity criterion of 8 out of 10 years of "complete" data for the years 1979 through 1988 were selected for the trends analyses. Each year with data also needed to satisfy the annual data completeness criterion. For carbon monoxide, nitrogen dioxide and sulfur dioxide continuous instruments, data containing at least 4380 hourly observations from each year were used. Bubbler data were not used in these analyses. In the case of ozone, the second daily maximum 1-hour concentration was selected only from those sites with at least 50 percent of the daily data for the ozone season. Total suspended particulate data met the completeness criterion if there were at least 30 samples for the year. Finally, in the case of the pollutant lead, both 24-hour and composite data were used in the trends analyses. For the 24-hour data, the annual maximum quarterly mean needed to satisfy the criterion of at least six samples per quarter in at least 3 of the 4 calendar quarters. Composite data were judged valid if at least two monthly samples were available for at least 3 of the 4 possible quarters. As mentioned previously, the 5-year trends are presented where no sites in the area met the above criteria. The same criteria described above were used except the site needed 4 out of 5 years to meet the historical continuity criterion.

Because this chapter only includes sites with sufficient data for trends, it is possible that an area could be violating a NAAQS, yet the trend graph still shows the area as not violating. The air quality trends for each of the pollutants show in most cases a "highest air quality statistic among trend sites." For example, the annual second maximum nonoverlapping 8-hour average in parts per million is used for CO. In St. Louis, the second maximums for 1986 and 1987 are below the NAAQS (9 ppm). However, a site which was not included (because it did not meet the historical continuity criterion of 8 out of 10 years) reported data not meeting the NAAQS. In 1988, EPA proposed that the St. Louis area be designated nonattainment and imposed a requirement to amend the area's implementation plan for air quality (SIP). Other areas may be violating the NAAQS but the statistics on the graphs do not show a violation because sites not meeting the completeness criteria were not included.

The CMSA/MSA area air quality trends focus on the period 1979 through 1988, complementing the 10-year national trends analyses in Chapter 3. The air quality trends in this chapter are based on information from monitoring sites within the CMSA/MSA areas as defined in the Statistical Abstract of the United States prepared by the U. S. Bureau of Census.[1]

Figure 5-1 shows the plotting convention used in trends analyses. For 1979 through 1988, maximum and minimum values are shown as well as the composite average of the sites used. The maximum and minimum values are measured concentrations. The values for the average concentration may include interpolated values from sites having incomplete data for a given year. In some years, the average value includes interpolated values from one or more sites, however in all years at least one measured value is included in the average. When only one site is available, or when the average concentration (which includes one or more interpolated values) exceeds the measured maximum value or is less than the measured minimum value, a maximum or minimum value is not plotted. Table 5-1 shows the air quality statistics used in the trends analyses for the 15 cities.

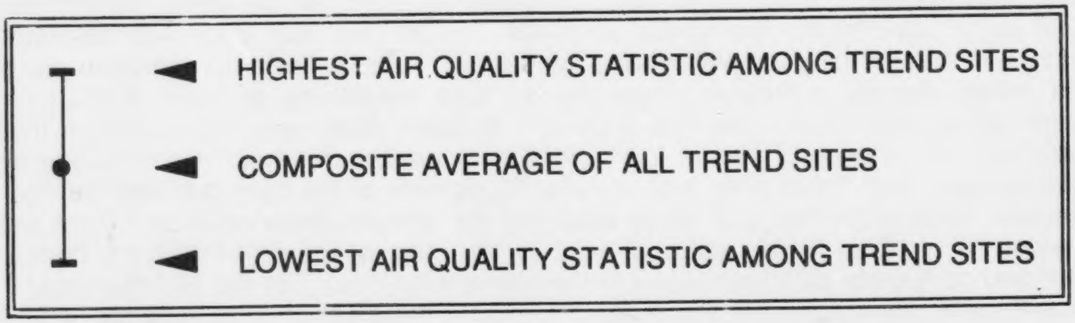
HIGHEST AIR QUALITY STATISTIC AMONG TREND SITES
COMPOSITE AVERAGE OF ALL TREND SITES
LOWEST AIR QUALITY STATISTIC AMONG TREND SITES

Figure 5-1. Illustration Of Plotting Conventions For Concentration Ranges Used In CMSA/MSA Area Trend Analysis.

The air quality data and trends presented in this chapter should not be used to make direct city-to-city comparisons, since the mix, configuration, and number of sites composing the area networks are different. Furthermore, other parameters, such as population density, transportation patterns, industrial composition, emission sources, and meteorological characteristics, also need to be considered.

TABLE 5-1. AIR QUALITY TREND STATISTICS

POLLUTANT	TREND STATISTICS *
Total Suspended Particulate	annual geometric mean
Sulfur Dioxide	annual arithmetic mean
Carbon Monoxide	second highest nonoverlapping 8-hour average
Nitrogen Dioxide	annual arithmetic mean
Ozone	second highest daily maximum 1-hour average
Lead	maximum quarterly average

* See Table 2-1 for a more detailed description of NAAQS

5.1 AIR QUALITY TRENDS

Figures 5-2 through 5-16 show the CMSA/MSA area trends for 1979 through 1988 for the six NAAQS pollutants. Tables 5-2 through 5-5 present a pollutant-specific summary of the overall concentration changes in each of the 15 areas. These areas are grouped into seven geographic regions: Northeast, Midatlantic, Midwest, South, Rocky Mountain, Southcoast, and Northwest.

Northeast - Boston, New York, Philadelphia
Midatlantic - Baltimore, Washington, DC
Midwest - Chicago, Detroit, St. Louis
South - Atlanta, Houston
Rocky Mountain - Denver, Phoenix
South Coast - Los Angeles
Northwest - Portland, Seattle

Composite geographic area averages of the 5- and 10-year change in air quality concentrations were calculated. In the individual geographic area averages, each city has equal weight, regardless of the number of monitors operating. For comparison to the national trends, however, each city's input is weighted by the number of monitors operating for a given pollutant. The following discussion addresses the findings.

5.1.1 TSP Trends

Long-term TSP Trend

The 15-city weighted average shows a 19 percent decrease over the 10-year period. Similarly, the national 10-year trend shows a 20 percent decrease. However, as mentioned previously in Chapter 3 of this report, EPA has determined that the measurements produced during the years 1979-1981 may be biased high due to the type of filters used to collect TSP. On a regional basis the South Coast had the least improvement with a 5 percent decrease, which was followed by the Midatlantic with a 11 percent decrease. The Midwest, Rocky Mountain, and the Northwest areas exceeded the national average by recording improvements of 23, 25, and 21 percent, respectively. The South at 17 percent and the Northeast at 15 percent, were just slightly below the national average.

On a city specific basis the cities with the most improvement in air quality were Houston with a 35 percent decrease in concentrations, Denver with a 29 percent decrease, and Chicago with a 28 percent decrease. All these areas were affected by the controls developed in the early 1980s and the later economic slowdown and recession in the energy fields. Also, these three cities had relatively high TSP levels in the base year 1979 of the trend. Conversely, the two cities which showed the least improvement over the last 10 years were Los Angeles and Atlanta. Los Angeles TSP concentrations only improved 5 percent for TSP over the last 10 years, primarily because their strict source controls were fully implemented in 1979 and they have experienced phenomenal growth during the trend period. Atlanta also has held its own in the face of rapid growth although they actually suffered a 1 percent increase in TSP levels over the trend period. The TSP concentrations in 1979, however, were relatively low when compared to the cities which experienced high levels of improvement.

Short-term TSP Trend

During the last 5 years, the overall TSP concentrations have flattened out. The national trend as well as the 15-city composite weighted average each indicate an improvement with a 1 percent decrease in the air quality. On a geographic basis, the Northeast, Midatlantic, Midwest, and South Coast areas show increasing trends in TSP concentrations of 3, 1, 6, and 1 percent, respectively. The South, Rocky Mountain, and Northwest areas show decreases in TSP concentrations of 8, 2, and 6 percent, respectively. On a city-specific basis, Denver and Portland have shown the greatest decrease of TSP concentrations of 15 percent and 9 percent, while St. Louis and Phoenix had the largest increases of 18 and 11 percent, respectively. Denver's improvement was apparently due in great part to the short-term slowdown in building construction. The increase in measured concentrations in the St. Louis area was due to growth in industrial emissions near Granite City, while the higher levels in Phoenix can be attributed to drier climatic conditions.

5.1.2 Lead Trends

Long-term Lead Trend

Because the 10-year trend period precedes the implementation of the lead standard, this pollutant had the fewest sites (26) which met the 10-year trend criteria in these 15 areas. The cities of Boston, New York, Detroit, St. Louis, and Atlanta had no sites, all the other cities had between 1 and 3 monitors with the exception of Chicago which had 10. The composite average, however, agreed remarkably well with the national trend with an 86 percent decrease in concentration versus an 89 percent decrease. This demonstrates the point that when a source's impact is truly ubiquitous i.e., lead from automobiles, and that source is reduced, the effectiveness of the source reduction can be tracked with a limited number of monitors.

The city of Seattle is an exception to this rule with its one site showing only a 44 percent decrease in concentration. This site was source oriented and near a smelter which was shut down in 1986.

Short-term Lead Trend

By looking at a 5-year trend, the number of sites qualifying in the 15 cities increased from 26 to 115. The only two cities which do not have a 5-year trend are Atlanta and Portland. Seattle's 5-year trend did not include the source oriented lead site, but did include two traffic oriented sites which were not included in the 10-year trend. Seattle's 5-year trend showed a 75 percent decrease. The 5-year composite trend for the 15 cities shows a 50 percent decrease in concentrations. When the source oriented sites in New York and St. Louis are not considered, the trend decrease of 74 percent more closely matches the national trend of 75 percent. The source oriented sites in New York and St. Louis are plotted and show a decrease of 20 percent in New York and an increase of 203 percent in St. Louis. The source oriented sites for New York are in Wallkill around an automobile battery reprocessing facility, and the sites in St. Louis are in Herculaneum around a primary lead smelter. The State of Missouri is currently pursuing the installation of better control technology for lead emissions.

5.1.3 SO_2 Trends

Long-term SO_2 Trend

The weighted average of 11 of the 15 cities which had sites that qualified for the trend analysis yielded a 23 percent reduction in concentrations as opposed to the national average reduction of 30 percent. The cities which did not qualify for the trend analysis, Washington, Atlanta, Phoenix, and Portland, all have low SO_2 levels and few if any large SO_2 sources. Chicago, Denver, and Seattle had reductions of 46, 45, and 43 percent, respectively, which are a result of control programs, economic and energy recessions, and the shutdown of the ASARCO smelter near Seattle.

Geographically, the Midatlantic (Baltimore data only) showed the least improvement with a 4 percent decline in concentrations and is followed by the Northeast at 9 percent and the South (Houston data only) at 17 percent. Those areas which equalled or exceeded the national average were the Midwest at 30 percent, the Rocky Mountain area at 33 percent, the South Coast at 33 percent, and the Northwest (Seattle data only) at 43 percent improvement.

Short-term SO_2 Trend

By looking at the 5-year trends, the number of SO_2 sites increased from 90 to 118 and the cities of Washington, and Atlanta are now included. With the exception of Philadelphia which showed no change over the past 5 years, all the cities except Washington, (+7 percent) and Atlanta (+1 percent) had decreasing trends. The increases are evidently due to greater electrical power demand. During the last 5 years the composite average of the 15 cities exceeded that of the national average with a decrease of 17 percent compared to 13 percent in air quality, respectively. Seattle leads the way with a 42 percent decrease during the last 5 years due to the closing of the ASARCO smelter.

5.1.4 CO Trends

Long-term CO Trend

With the exception of lead, CO has shown the most improvement. At the beginning of the 10-year trend, 13 cities had some second high 8-hour maximum averages above the level of the standard and 10 cities had composite means of all their monitors' second high maximum values over the standard. By 1988, only 8 cities had data used in the trends analyses with second high maximum values over the standard and only 2 cities had composite means of the second high maximum value above the level of the standard.

The national average and the 15-city weighted average are identical with a 28 percent improvement. Regionally, the largest improvement was registered in the Northeast with 42 percent improvement followed by the Midwest and Northwest at 35 and 34 percent, and the Rocky Mountain, Midatlantic and South at 29, 23, and 22 percent, respectively. Portland, with a vigorous motor vehicle inspection and maintenance (I/M) program and a massive effort in rapid transit systems (bus and light rail) over the last 10 years, and St. Louis showed the most improvement with a decrease of 46 percent in concentration. These cities were followed closely by Boston and New York at 45 percent each, and Chicago with 42 percent, each due to the implementation of I/M programs, transportation control measures, and the Federal Motor Vehicle Control Program. Houston and Los Angeles registered only one-half of the national average improvement of 14 percent. Houston had only 1 CO site that met the 10-year criteria and had relatively low readings at the beginning of the trend period. Los Angeles had already implemented the strictest controls in the country and has continued to register improvement in spite of growth.

Short-term CO Trend

Once again the composite weighted average of the 15 cities mimicked the national average with a decrease of 15 percent versus 16 percent, respectively. Although all the cities had decreasing trends in the 10-year period, Houston, Seattle, and Los Angeles had deteriorations of 5, 8, and 10 percent, respectively during the last 5 years. In the case of Houston, the apparent increase is due to the inclusion of higher values from additional monitors used for the 5-year trend and an increase in emissions due to additional vehicle miles traveled in the area. The expanded network in the last 5 years has identified increasing trends. The Los Angeles increase is also a function of its growth and possibly changing traffic patterns. Recently, Los Angeles does not appear to have a pronounced morning and evening rush hour period, but is congested for all normal daylight driving hours, thus masking any diurnal pattern of CO emissions and concentrations.

5.1.5 NO_2 Trends

Long-term NO_2 Trend

This is the pollutant with the most cities missing data although the 8 cities contributing to the trend showed an improvement almost twice that of the national average, 13 percent versus 7 percent. The cities that had no site which met the 10-year trend criteria were Baltimore, Washington, Detroit, Atlanta, Phoenix, Portland, and Seattle. Of the cities that had trend data from five or more monitors, the trends were remarkably consistent with Los Angeles at 14 percent improvement, Philadelphia at 15 percent, and St. Louis at 17 percent improvement.

The only areas which showed a lack of improvement were Chicago with no change, 2 percent deterioration in New York, and a 12 percent deterioration in Boston. This change was based on 2, 3, and 1 monitors, respectively. On a Regional basis there was no data from the Midatlantic and Northwest. No change was recorded in the Northeast, and there was a 9 percent improvement in the Midwest, a 14 percent improvement in the Rocky Mountain, and a 39 percent improvement in the South. The 39 percent improvement in the South is based upon only 2 monitors in Houston.

Short-term NO_2 Trend

The 5-year trend picked up 3 of the 7 cities that were missing in the 10-year trend. The additional cities included in the trend are Baltimore, Washington, and Atlanta. The total number of sites used increased from 35 to 72 as well. The recent 5-year trend for NO_2 has been almost flat with the national trend increasing by 1 percent and the 15-city composite weighted average decreasing by 1 percent. Boston and Atlanta continue to show the greatest increase in NO_2 levels over the last 5 years with 10 percent and 13 percent increases, respectively. Washington leads the way in decreases with 10 percent.

5.1.6 O_3 Trends

Long-term O_3 Trend

The national trend showed a 1 percent deterioration between 1979 and 1988 while the 15-city weighted average showed a 4 percent increase in ozone levels over the same period. This increase has been in part attributed to summer meteorology for 1988. On the average, 1988 was the third hottest summer in the past 50 years and this effect was most noticeable in the Northeast, Midatlantic, and Midwest regions where the average city increase was 15 percent over the 10-year period. The two cities which showed the most decrease in ozone levels over the last 10-year period were those cities which have been historically associated with high levels of ozone and where the concentrations in 1979 were high enough to compensate for the elevated values in 1988. These cities are Los Angeles (22 percent decrease) and Houston (24 percent decrease). Denver was the only other city to show a decrease (14 percent) and did not experience the general increase in 1988 that was seen primarily in the Midwest, Northeast, and Midatlantic areas.

Phoenix showed the greatest deterioration of 35 percent over the 10-year period. The cause of this increase is that the base year of 1979 was unusually low (.079 ppm) and the lowest of the 10-year period. Note that the trend was highly variable from year to year over the period.

Short-term O_3 Trend

The recent trend, as was the 10-year trend, was dominated by the hot summer of 1988. Nationally, ozone levels increased 9 percent and the 15 city average increased 11 percent. The increases were most apparent in the Eastern part of the United States as noted above where the summer of 1988 was the third hottest summer since 1931, and this contributed to the increase in O_3 levels. In the Northeast, Midatlantic, and Midwest, average increases of 18, 25, and 19 percent, respectively, were recorded. In the Rocky Mountain area, where the summer of 1988 was typical compared to the 50-year average temperature, the ozone levels actually decreased by 1 percent.

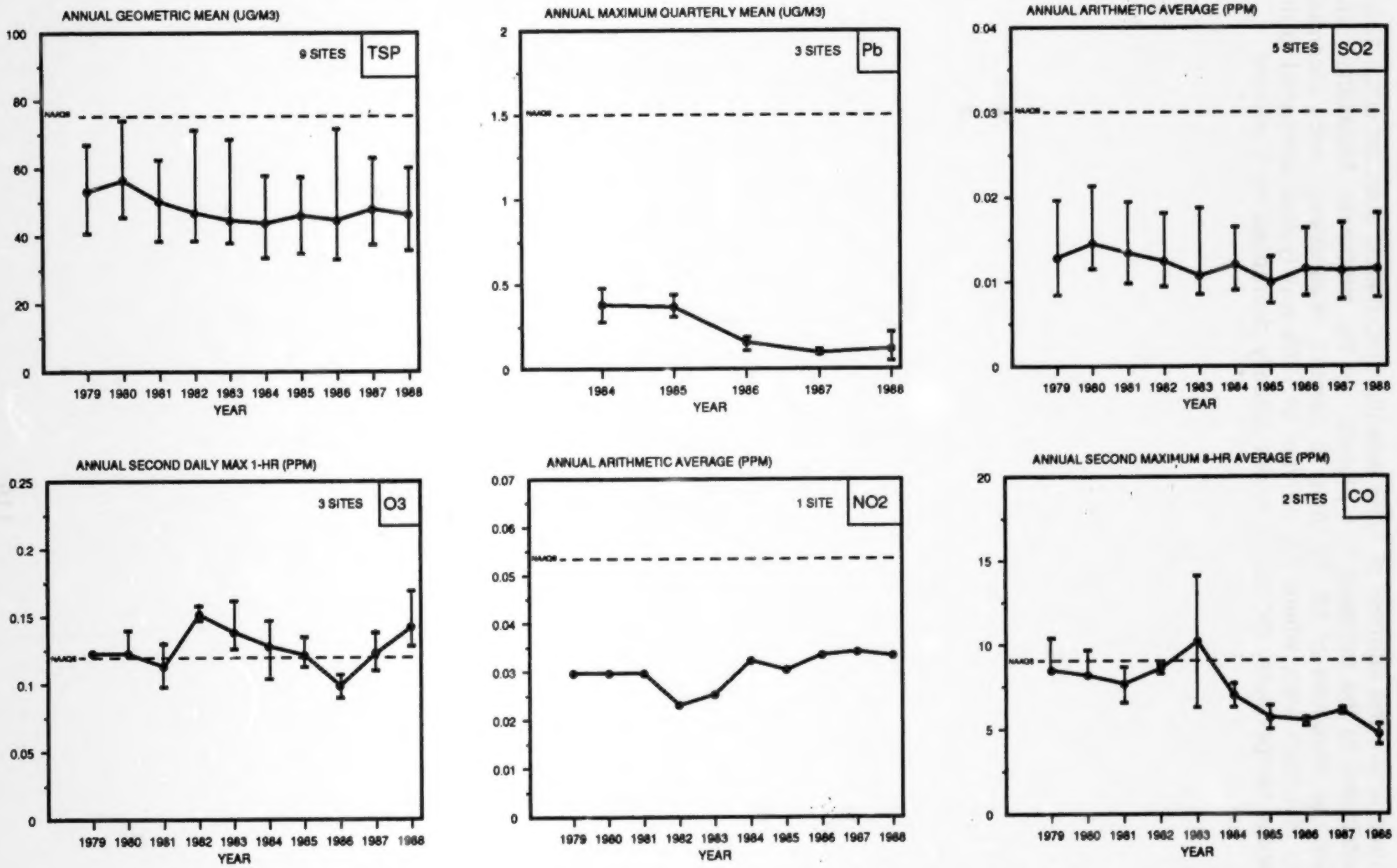

Figure 5-2. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the Boston-Lawrence-Salem, MA-NH Consolidated Metropolitan Statistical Area, 1979-1988, 1984-1988 Trend Years for Lead.

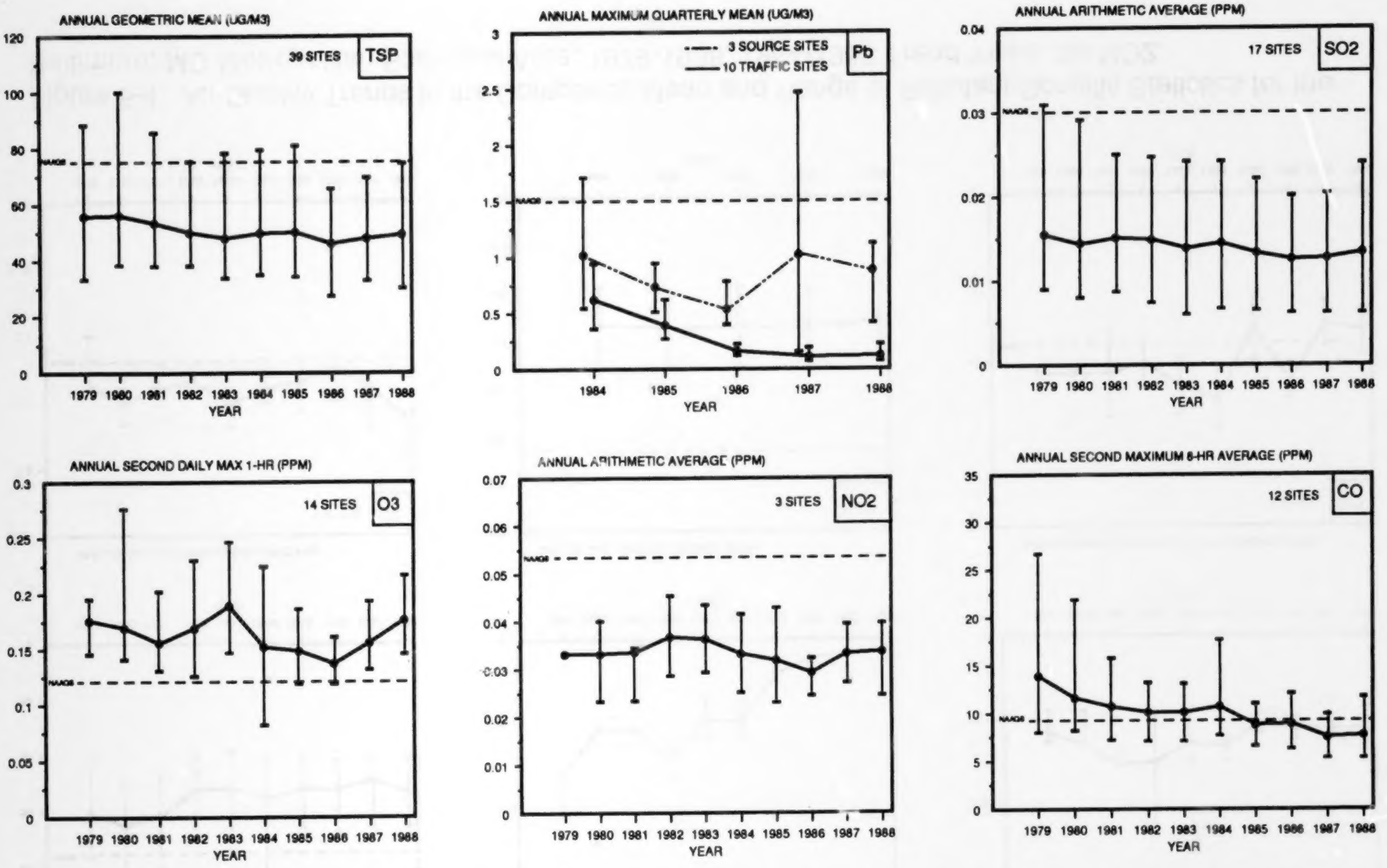

Figure 5-3. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the New York-Northern New Jersey-Long Island, NY-NJ-CT Consolidated Metropolitan Statistical Area, 1979-1988, 1984-1988 Trend Years for Lead.

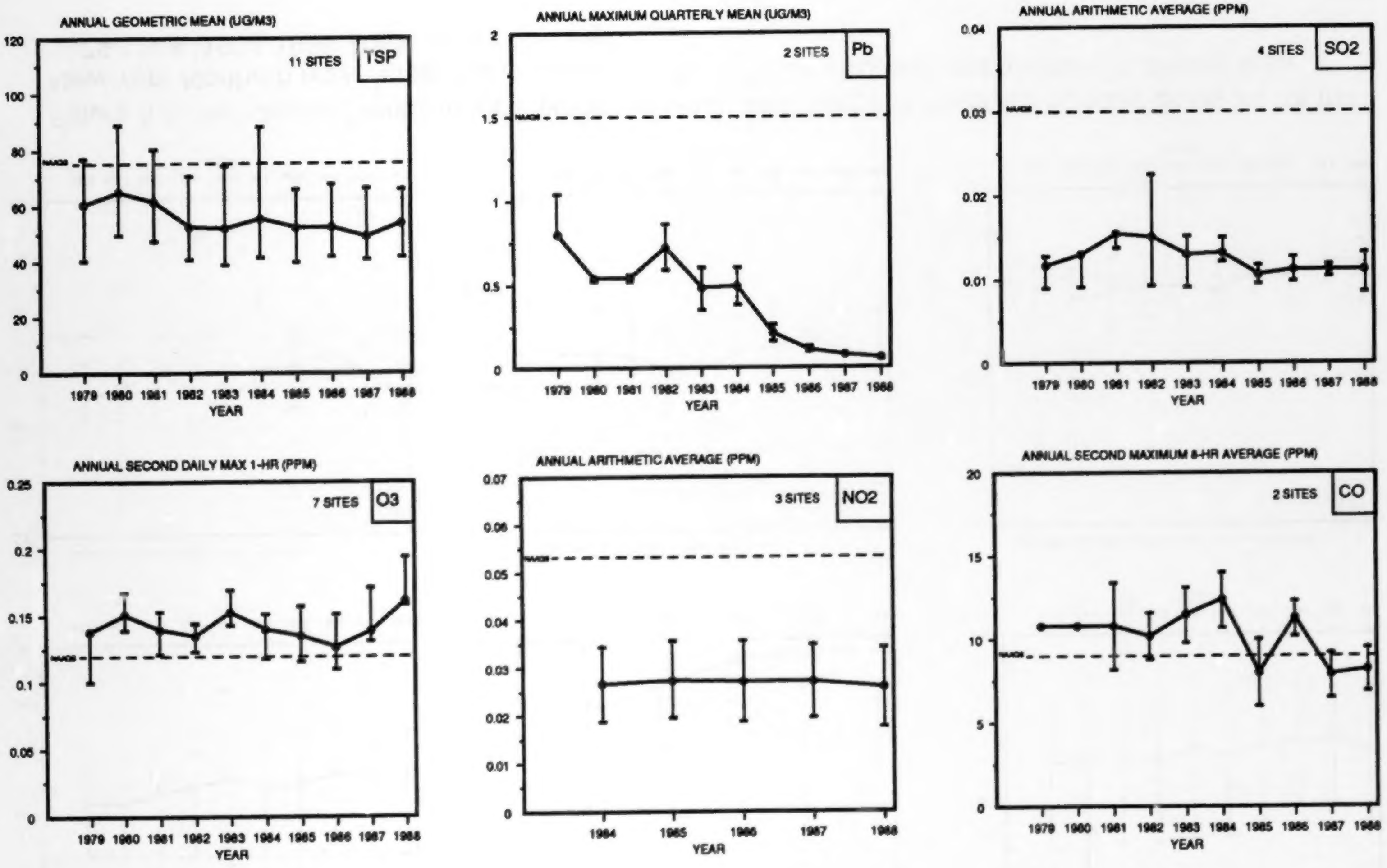

Figure 5-4. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the Baltimore, MD Metropolitan Statistical Area, 1979-1988, 1984-1988 Trend Years for NO2.

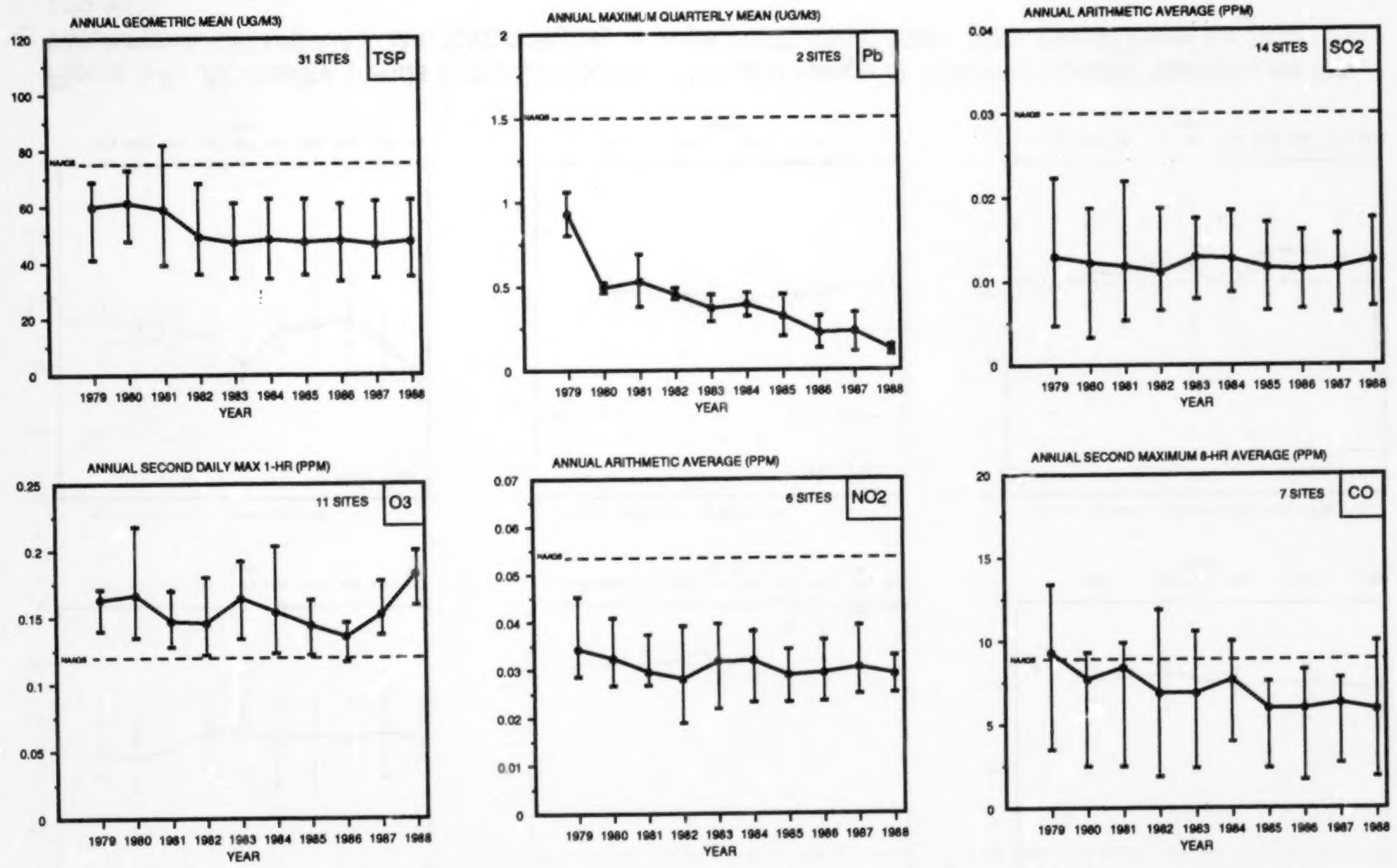

Figure 5-5. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the Philadelphia-Wilmington-Trenton, PA-NJ-DE-MD Consolidated MetropolitanStatistical Area, 1979-1988.

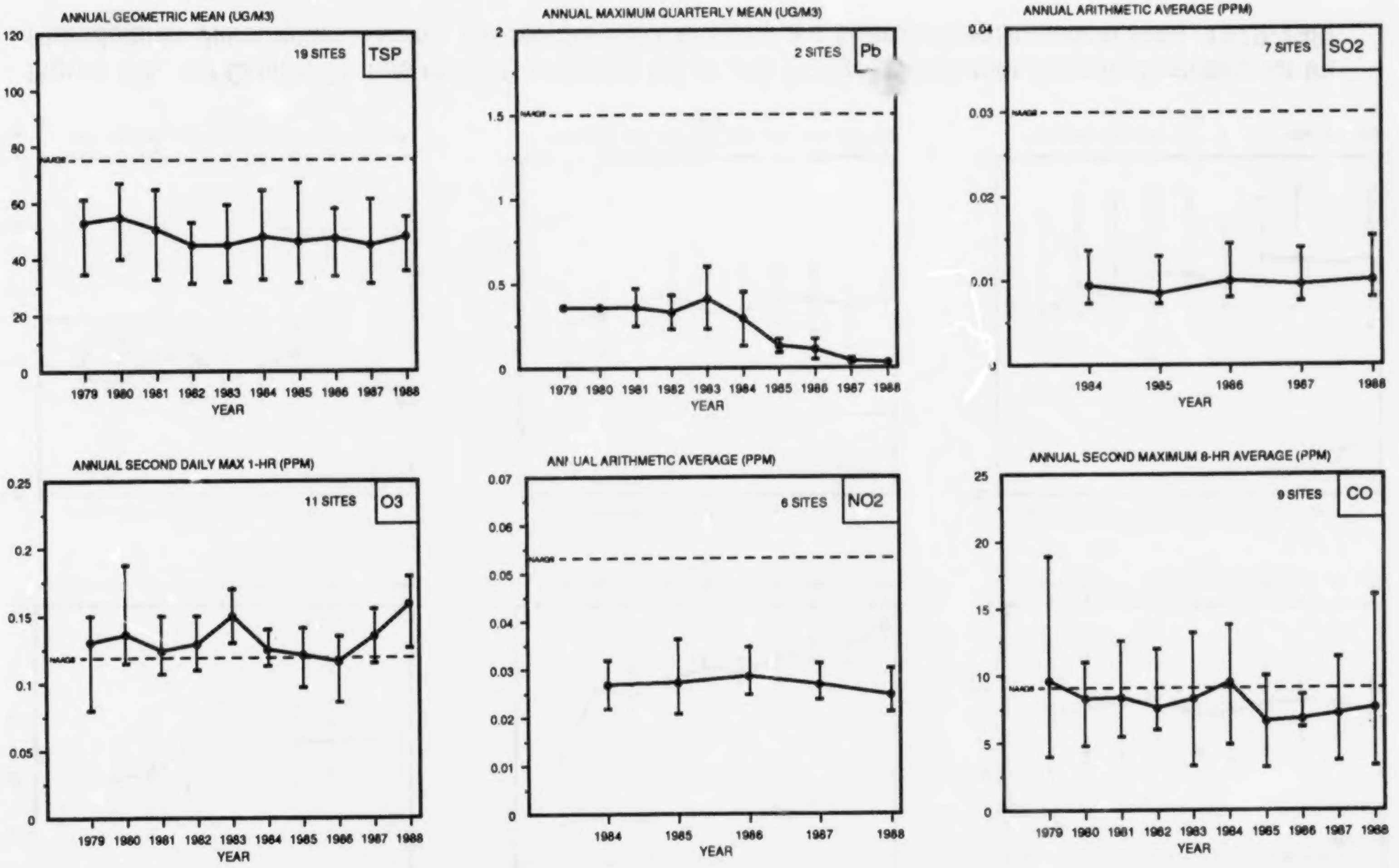

Figure 5-6. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the Washington, DC-MD-VA Metropolitan Statistical Area, 1979-1988, 1984-1988 Trend Years for SO2 and NO2.

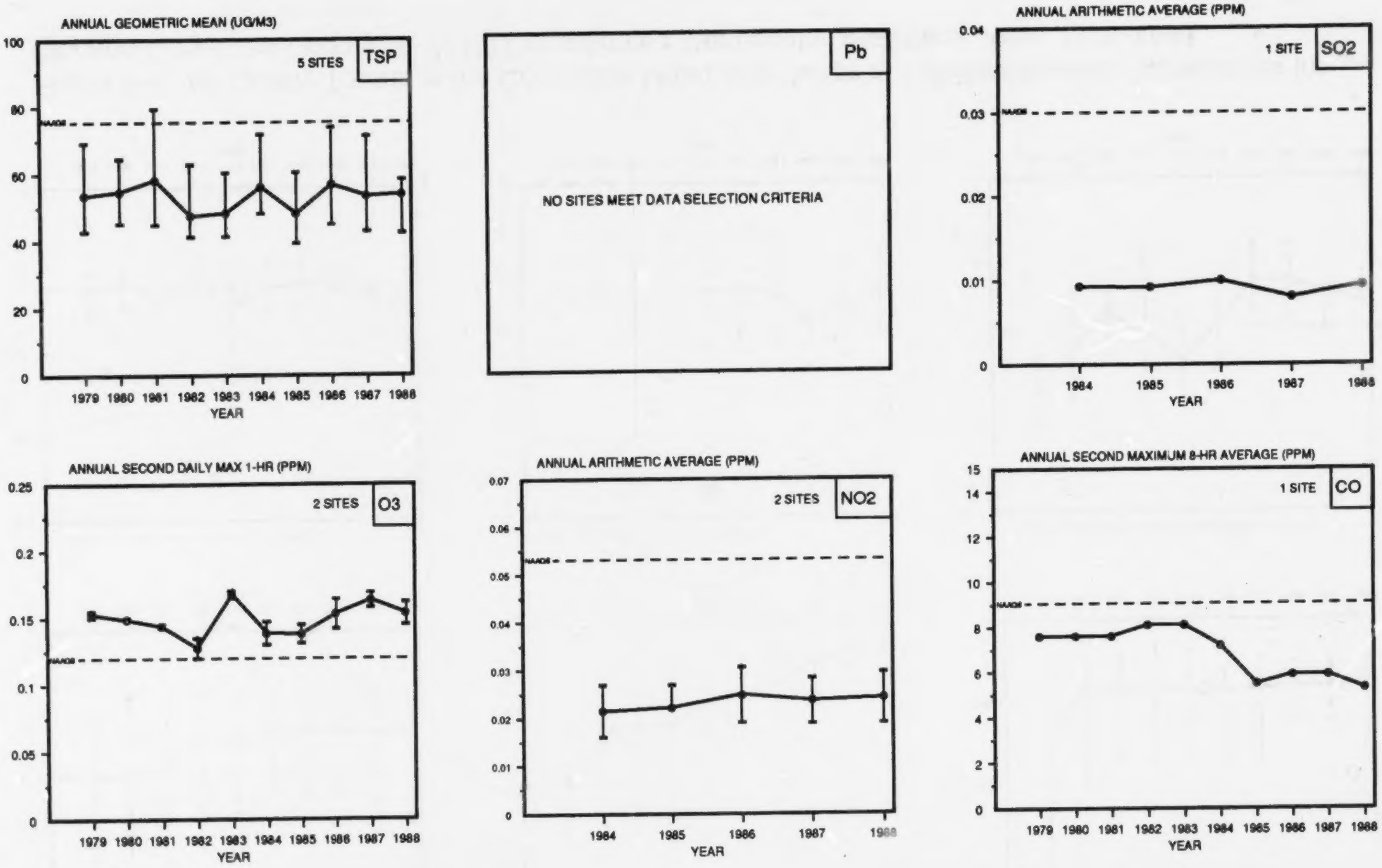

Figure 5-7. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the Atlanta, GA Metropolitan Statistical Area, 1979-1988, 1984-1988 Trend Years for SO2 and NO2.

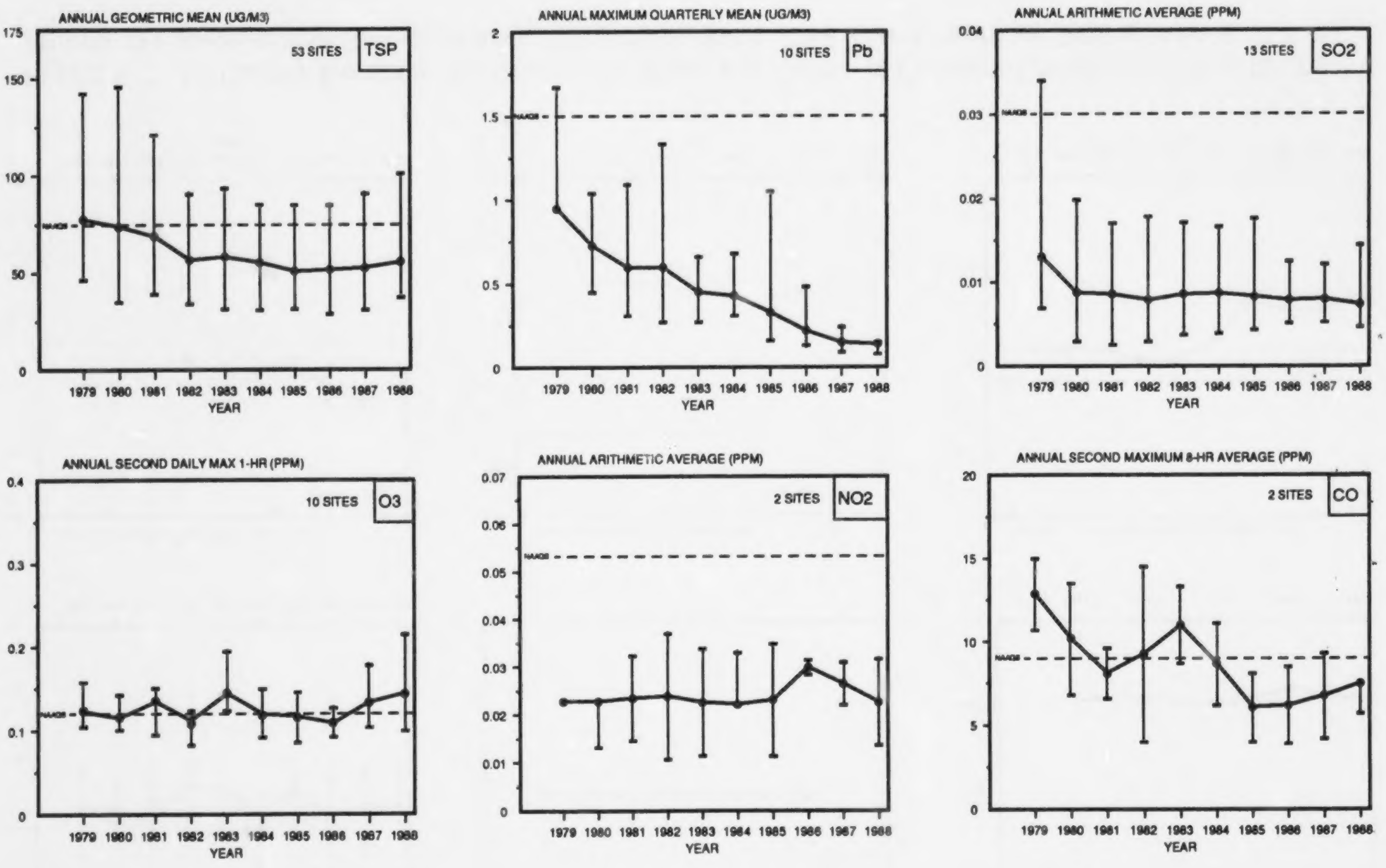

Figure 5-8. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the Chicago-Gary-Lake County, IL-IN-WI Consolidated Metropolitan Statistical Area, 1979-1988.

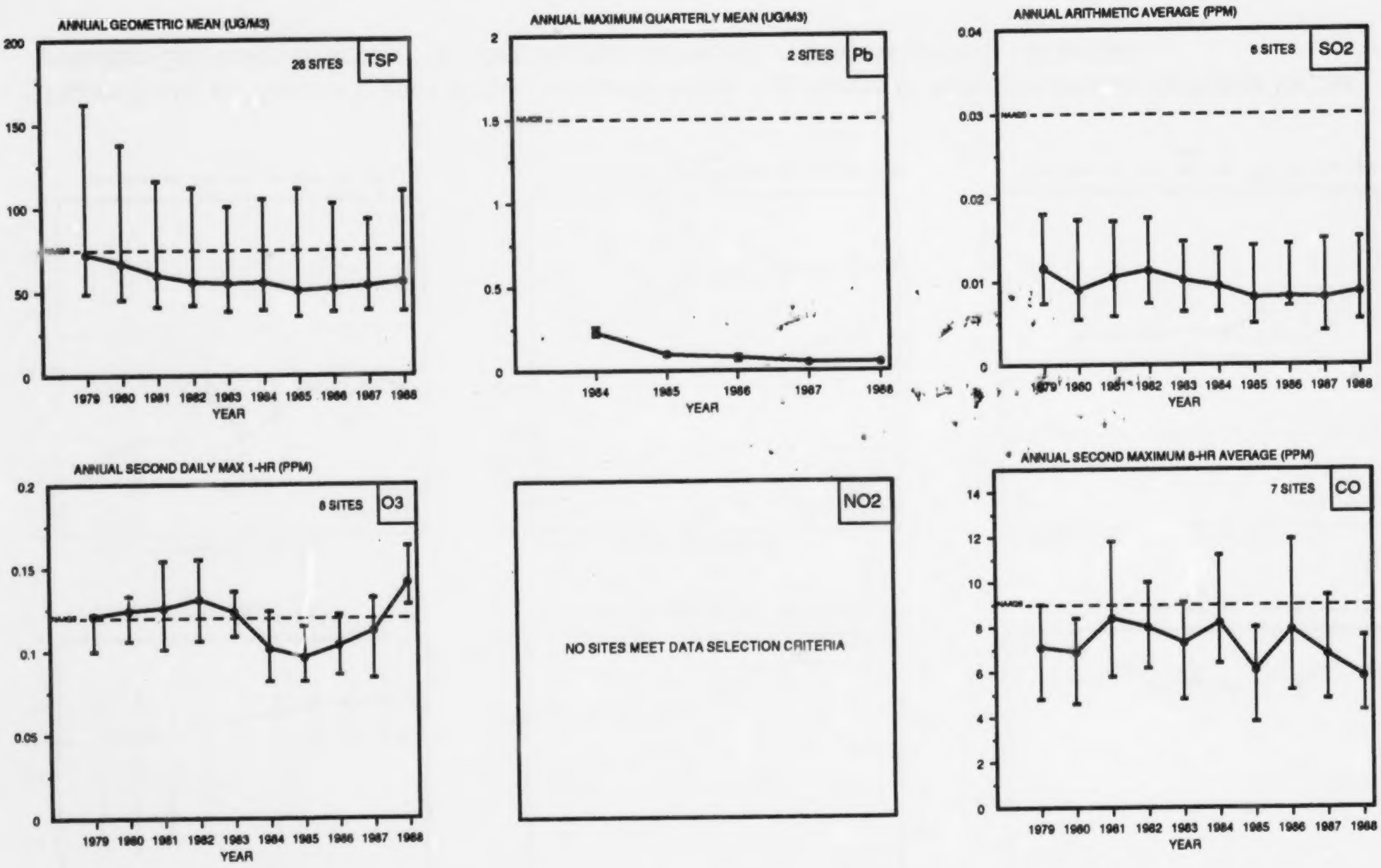

Figure 5-9. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the Detroit-Ann Arbor, MI Consolidated Metropolitan Statistical Area. 1979-1988,1984-1988 Trend Years for Lead.

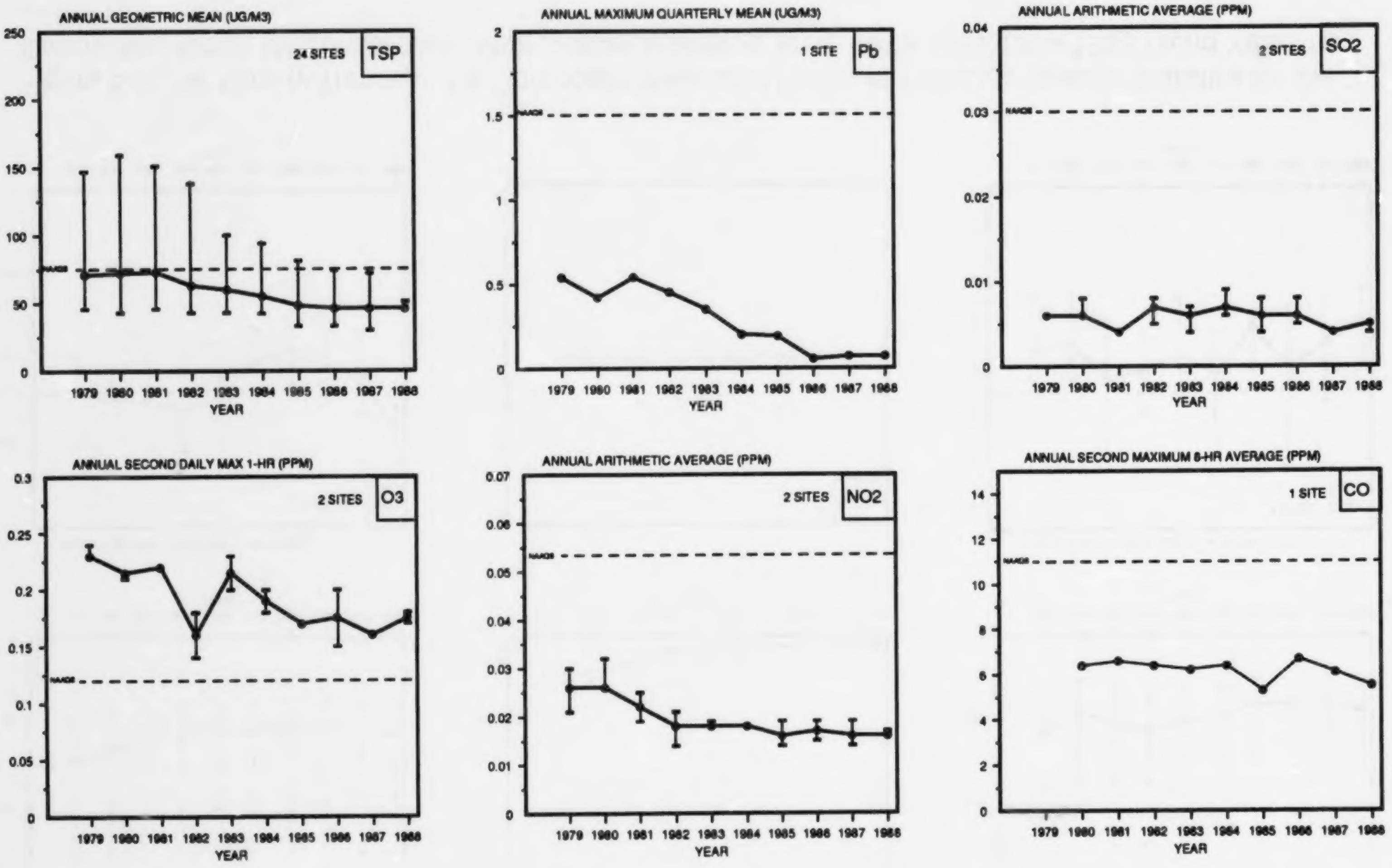

Figure 5-10. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the Houston-Galveston-Brazoria, TX Consolidated Metropolitan Statistical Area, 1979-1988.

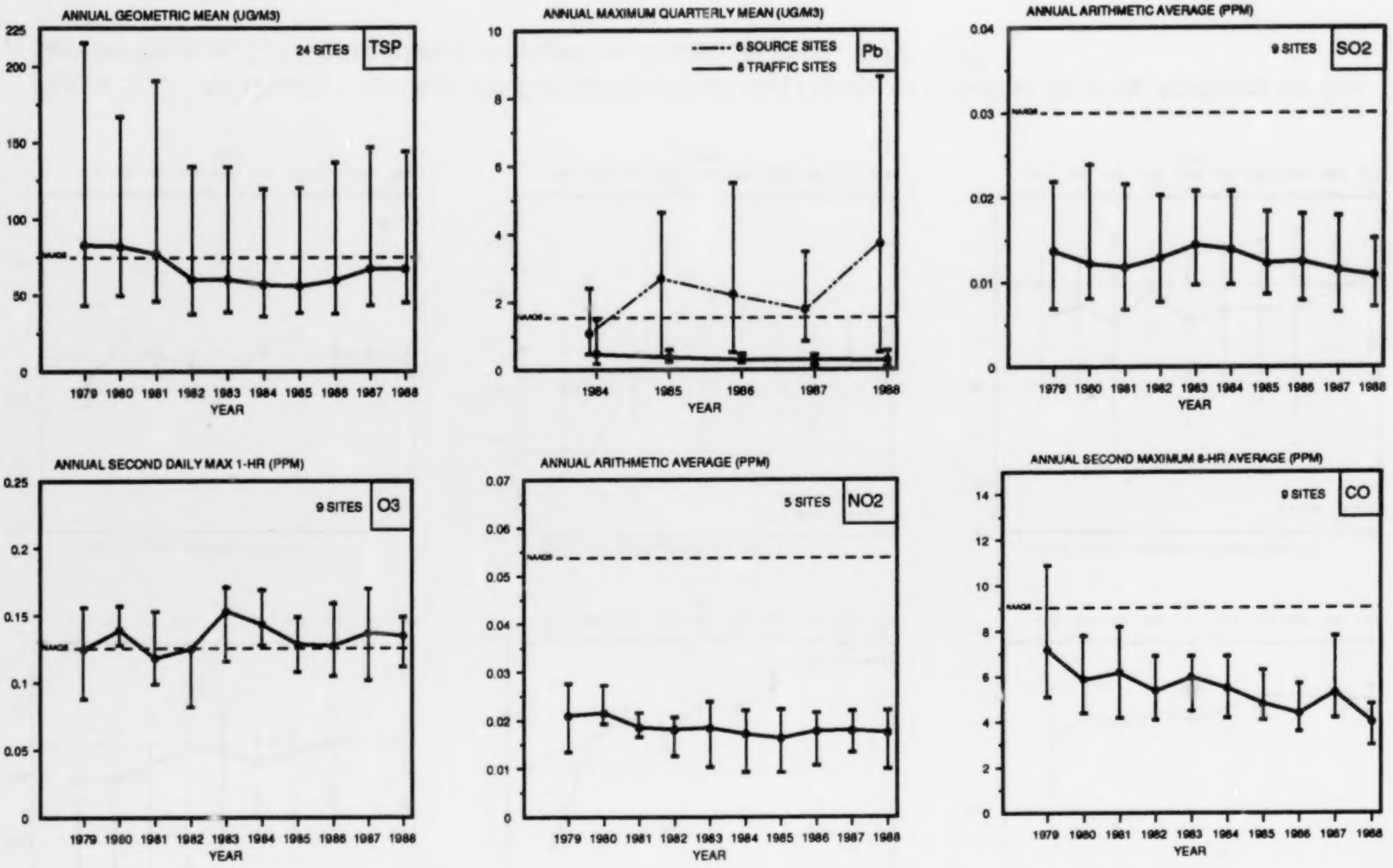

Figure 5-11. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the St. Louis, MO-IL Metropolitan Statistical Area, 1979-1988, 1984-1989 Trend Years for Lead.

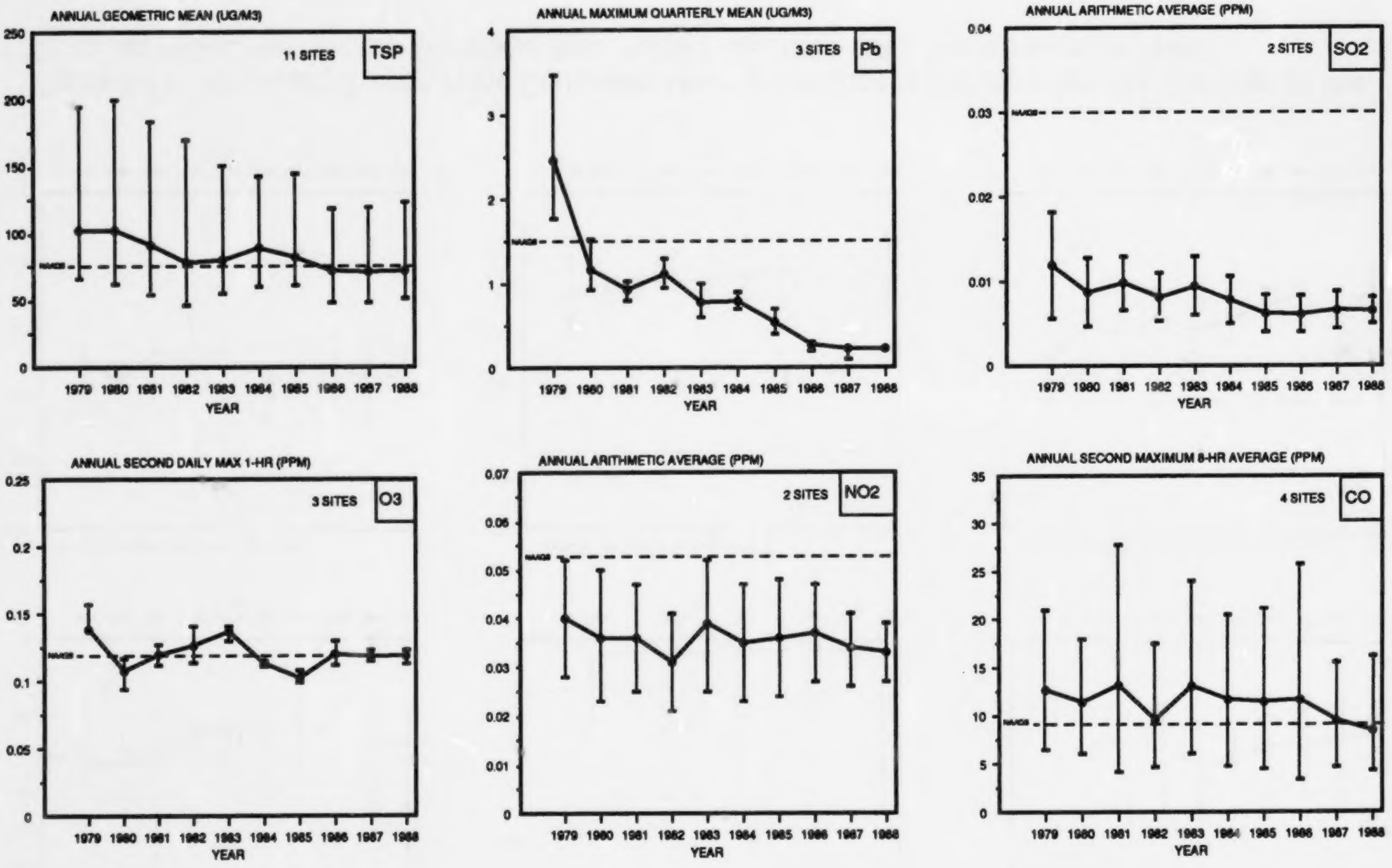

Figure 5-12. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the Denver-Boulder, CO Consolidated Metropolitan Statistical Area, 1979-1988.

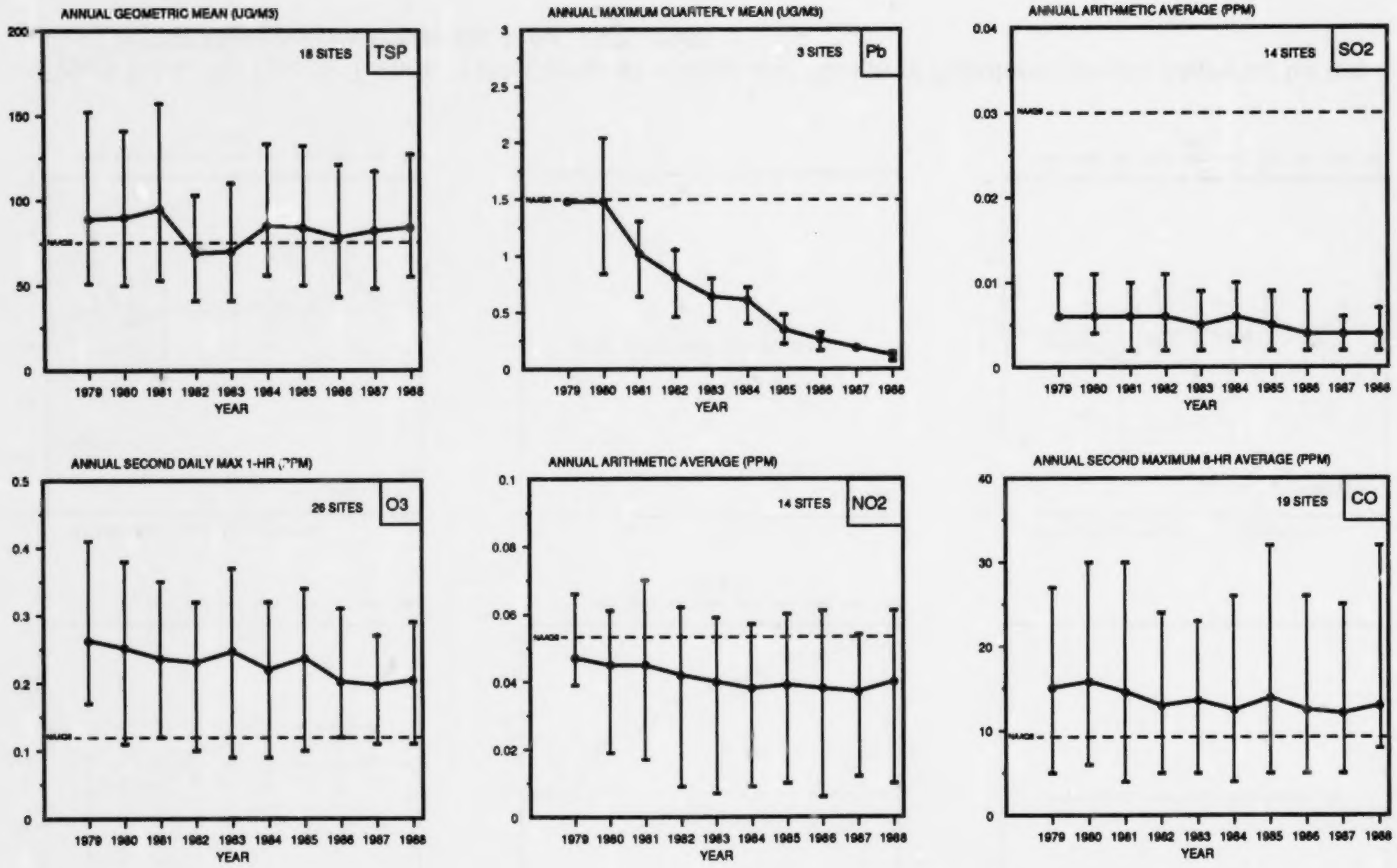

Figure 5-13. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the Los Angeles-Anaheim-Riverside, CA Consolidated Metropolitan Statistical Area, 1979-1988.

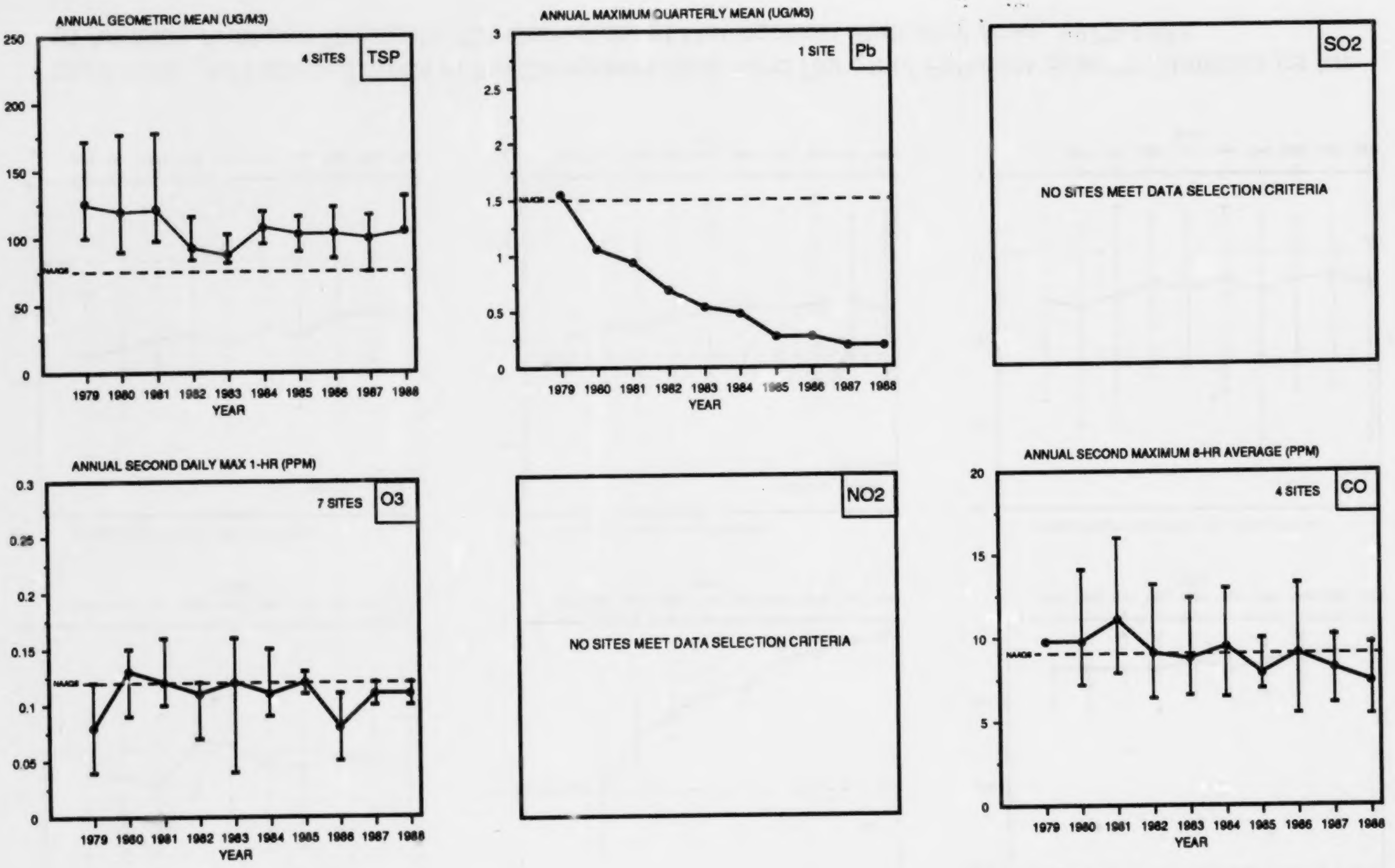

Figure 5-14. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the Phoenix, AZ Metropolitan Statistical Area, 1979-1988.

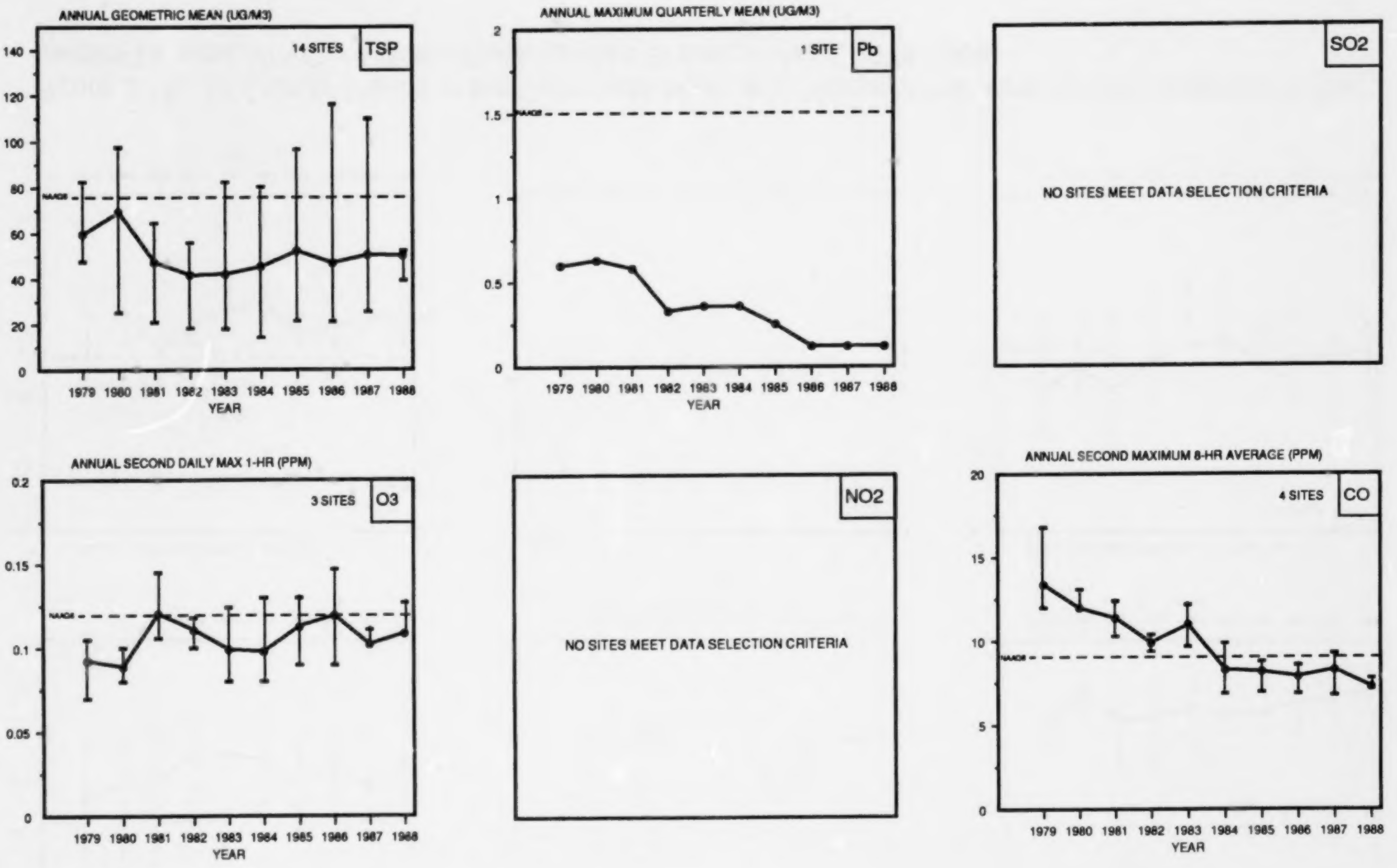

Figure 5-15. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the Portland-Vancouver, OR-WA Consolidated Metropolitan Statistical Area, 1979-1988.

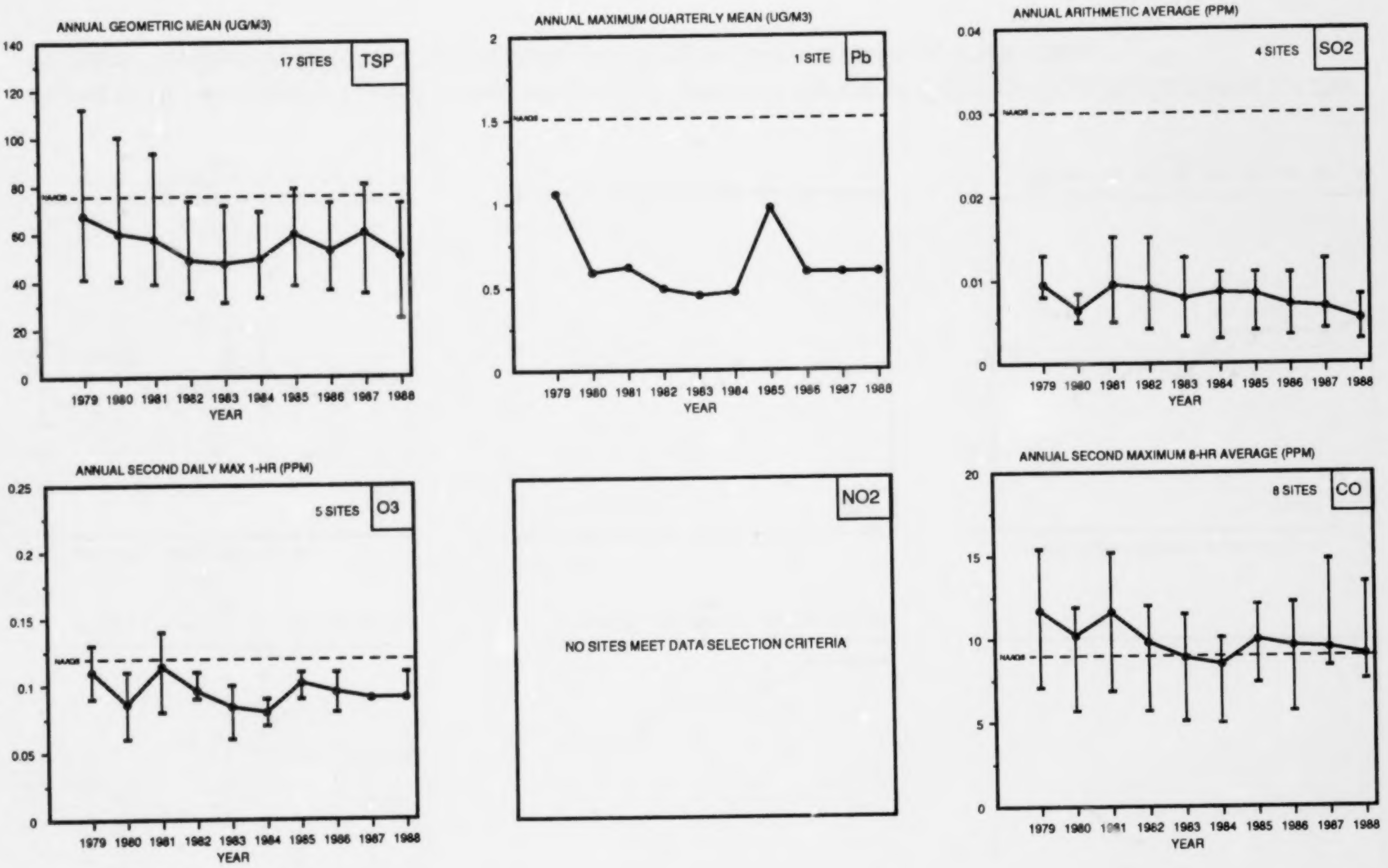

Figure 5-16. Air Quality Trends in the Composite Mean and Range of Pollutant-Specific Statistics for the Seattle-Tacoma, WA Consolidated Metropolitan Statistical Area, 1979-1988.

TABLE 5-2. Percent Change in Air Quality Trend Statistics 1979 Through 1988

		TSP	Pb	SO_2	CO	NO_2	O_3
National Average		- 20	- 89	- 30	- 28	- 7	+ 1
Northeast	Boston	- 13	-	- 10	- 45	+ 12	+ 16
	New York	- 12	-	- 14	- 45	+ 2	0
	Philadelphia	- 21	- 87	- 3	- 37	- 15	+ 12
Midatlantic	Baltimore	- 12	- 93	- 4	- 24	-	+ 17
	Washington, DC	- 10	- 92	-	- 21	-	+ 21
Midwest	Detroit	- 23	-	- 25	- 18	-	+ 17
	Chicago	- 28	- 85	- 46	- 42	0	+ 15
	St. Louis	- 19	-	- 20	- 46	- 17	+ 8
South	Atlanta	+ 1	-	-	- 30	-	+ 1
	Houston	- 35	- 87	- 17	- 14	- 39	- 24
Rocky Mtn.	Denver	- 29	- 91	- 45	- 33	- 17	- 14
	Phoenix	- 21	- 88	-	- 25	-	+ 35
South Coast	Los Angeles	- 5	- 92	- 33	- 14	- 14	- 22
Northwest	Portland	- 16	- 80	-	- 46	-	+ 19
	Seattle	- 25	- 44	- 43	- 22	-	+ 10
Composite Average (weighted)		- 19	- 86	- 23	- 28	- 13	+ 4

TABLE 5-3. Percent Change in Air Quality Trend Statistics 1979 Through 1988 by Geographic Regions

	TSP	Pb	SO_2	CO	NO_2	O_3
National Average	- 20	- 89	- 30	- 28	- 7	+ 1
Composite	- 19	- 86	- 23	- 28	- 13	+ 4
Northeast	- 15	- 87	- 9	- 42	0	+ 9
Midatlantic	- 11	- 93	- 4	- 23	-	+ 19
Midwest	- 23	- 85	- 30	- 35	- 9	+ 13
South	- 17	- 87	- 17	- 22	- 39	- 12
Rocky Mtn.	- 25	- 90	- 45	- 29	- 17	+ 11
South Coast	- 5	- 92	- 33	- 14	- 14	- 22
Northwest	-21	- 62	-43	- 34	-	+ 15

TABLE 5-4. Percent Change in Air Quality Trend Statistics 1984-1988

		TSP	Pb	SO_2	CO	NO_2	O_3
National Average		- 1	-75	- 13	-16	+ 1	+ 9
Northeast							
	Boston	+ 8	-68	+ 2	-44	+10	+15
	New York	+ 2	-34	- 8	-26	+ 2	+21
	Philadelphia	- 2	-79	- 14	-28	- 8	+18
Midatlantic							
	Baltimore	0	-86	- 14	-31	- 3	+20
	Washington, DC	+ 3	-86	+ 7	-20	-10	+29
Midwest							
	Detroit	- 2	-78	- 6	-36	-	+38
	Chicago	+ 2	-82	- 23	-13	- 2	+19
	St. Louis	+18	+121	- 19	-18	- 5	+ 1
South							
	Atlanta	- 5	-	+ 1	-26	+13	+11
	Houston	-11	-72	- 20	+ 5	- 3	0
Rocky Mtn.							
	Denver	-15	-71	- 17	-25	- 6	+ 4
	Phoenix	+11	-74	-	-19	-	- 5
South Coast							
	Los Angeles	+ 1	-81	- 29	+10	+ 3	- 6
Northwest							
	Portland	- 9	-	-	-15	-	+11
	Seattle	- 3	-75	- 42	+ 8	-	+22
Composite Average (weighted)		- 1	-50	- 17	-15	- 1	+11

TABLE 5-5. Percent Change in Air Quality Trend Statistics 1984 Through 1988 by Geographic Regions

	TSP	Pb	SO_2	CO	NO_2	O_3
National Average	-1	-75	-13	-16	+1	+ 9
Composite	-1	-50	-17	-15	-1	+11
Northeast	+3	-60	- 2	-33	+1	+18
Midatlantic	+1	-86	- 4	-26	-7	+25
Midwest	+6	-13	-16	-22	-4	+19
South	-8	-72	-10	-11	+5	+ 6
Rocky Mtn.	-2	-73	-17	-22	-6	- 1
South Coast	+1	-81	-29	+10	+3	- 6
Northwest	-6	-75	-42	- 4	-	+17

5.2 REFERENCES

1. Statistical Abstract of the United States, 109th Edition, U.S. Bureau of the Census, Washington, DC, January 1989.